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Changes in carotenoid intake from fruit and vegetables in the Spanish population over the period 1964–2004

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Abstract

Objective: To assess changes in carotenoid intake based on the variations in the consumption of fresh fruit and vegetables in the Spanish population over the period 1964–2004.

Design: Consumption data of fresh fruit and vegetables from Family Budget Surveys carried out in 1964, 1980, 1990 and 2004. Consumption data (g per person per day) accounted for >90% of fruit and vegetable consumption at each time point. Quality controlled high-performance liquid chromatography analysis of the carotenoid composition of Spanish fruit and vegetable was used.

Subjects: Randomly selected, private households throughout Spain (20 800 households in 1964, 30 311 households in 1980, 21 155 households in 1990 and 6000 households in 2004). Twelve vegetables and 16 fruits representing 89–96% of the total consumption of fresh fruit and vegetables were used.

Results: Individual consumption of fruit and vegetables has changed over this period, altering the total and individual intake of carotenoids. Total carotenoid intake increased from 2.5 mg per person per day in 1964 to 4.1 mg per person per day in 1990, with a decrease to 3.3 mg per person per day in 2004. These increments are due to an increase in lycopene, α- and β-carotene, while a decrease in lutein and zeaxanthin is observed during the last decade. A continuous and consistent decrease in the relative contribution of lutein in the diet is observed over the period studied.

Conclusion: Although the consumption of fruit and vegetables is still consistent with a Mediterranean-type pattern, modifications in the consumption of individual fruits and vegetables have provoked changes in total and specific carotenoid intake with potential relevance in human health.

Keywords
Carotenoids
β-Carotene
Lutein
β-Cryptoxanthin
Lycopene
Family Budget Survey

Carotenoids constitute one of the major groups of phytochemicals in human diets. Apart from the provitamin A activity displayed by some of them, several other biological activities have been reported, including antioxidant capacity, blue light filtering, immune modulation and regulation of cell differentiation and apoptosis[1–4].

In developed countries, 70–90% of carotenoid intake comes from fruit and vegetable consumption. Of the more than 50 carotenoids present in frequently consumed foods in Western diets, only a few are present in significant amounts, including β-carotene, α-carotene, β-cryptoxanthin, lutein, zeaxanthin and lycopene[5].

In most diets, the majority of carotenoids are derived from a few fruits and vegetables (i.e. green vegetables, carrots, tomatoes and tomato products), although estimated intakes of carotenoids vary widely on an individual, regional and national level, and significant seasonal variations have also been reported in some countries (e.g. Spain)[6–9]. In addition, the assessment of carotenoid intake, at both individual and group level, has been shown to be complicated mainly because of the high variability in within-subject and between-subject intake, inaccuracies associated with methods of dietary assessment, and inconsistencies in food composition tables and databases[5,10].

It is widely assumed that serum concentrations of carotenoids reflect, at least to some extent, the consumption of carotenoid-containing foods and, thus, serum carotenoid status may be used as an index related to a healthy diet[11]. Inadequate consumption of fruit and vegetables has been identified as a probable risk factor in relation to hypertension, cardiovascular disease and cancer[12–14], and, consistently, epidemiological studies have shown that high carotenoid intake and/or serum

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concentrations are associated with lower risk for developing chronic and degenerative diseases[15–17].

However, in the last decades, economic development, the role of consumers, changes in food production and food technology and the global market (i.e. distribution and commercialisation of food products) have modified the food market within the European Union[14]. Thus, to understand better the potential effect on health associated with changes in dietary patterns and to provide evidence-based criteria to promote fruit- and vegetable-rich diets, we aimed to assess the trends and changes in carotenoid intake based on the variations in fruit and vegetables consumption over the last 40 years in the Spanish population.

Methods

To estimate total and individual carotenoid intake as well as the main contributors and to study changes over the last 40 years, available data on food consumption at four time points in Spain were considered (1964, 1980, 1990 and 2004). These measures correspond to the Family Budget Surveys carried out by the National Institute of Statistics and other studies from the Spanish Ministry of Agriculture, Fishing and Food[18–21], and cover from the earliest to the last available dataset in the Spanish population. In these surveys, a nationwide representative sample of randomly selected private households was studied in 1964 (20 800 households), 1980 (30 311 households), 1990 (21 155 households) and 2004 (6000 households). To assess food consumption, the foods brought into the home during a 1-week period and distributed over 1 year were recorded, except for data in 2004 where the foods purchased were recorded daily and the frequency of results collected monthly.

Since different records were employed in each study (and thus individual data collected), to increase homogeneity and allow comparability, some food items were grouped; thus, green leafy vegetables reflect spinach and beet intake, peppers included green and red varieties, and lettuce involved leafy and iceberg varieties. A total of 12 vegetables (including potatoes) and 16 fruits representing at least 89% of the total consumption of fresh fruits and vegetables in Spain at the four time points studied were finally used. For comparative purposes, the relative contribution of each carotenoid to total (carotenoid) intake at each time point was also calculated.

The individual carotenoid content (lutein, zeaxanthin, β-cryptoxanthin, lycopene, α-carotene and β-carotene) of each of these items was multiplied by the amount consumed (g per person per day) at each time point and this provided an estimate of the carotenoid contribution of the food. The carotenoid intakes from these foods were added up to yield individual and total carotenoid intake as well as their relative contribution. The carotenoid concentration data came from quality controlled high-performance liquid chromatography (HPLC) analysis of fresh fruits and vegetables as customarily eaten in Spain[22–24]. The findings were gathered in tables that specifically reflect the carotenoid content of foods and in which data quality has been evaluated as highly acceptable[25].

Results

The relative contribution of each fruit and vegetable and the individual intake of carotenoids (μg per person per day) over the 40-year period in the Spanish population is shown in Table 1. As shown, the consumption of seven vegetables and five fruits contributed >90% of the consumption of each carotenoid at any time point, although the relative importance of some food items has changed significantly throughout this period, i.e. carrots, oranges, tangerines, potatoes and tomato. According to these data, during the last 40 years, total carotenoid intake from fresh fruits and vegetables increased from 2.5 mg per person per day in 1964 to 4.1 mg per person per day in 1990, with a decrease to 3.3 mg per person per day in 2004.

Compared with 1964 data, intake increased for all carotenoids except for lutein and zeaxanthin. This increase was substantial for the period 1964–1990 especially for β-cryptoxanthin, α- and β-carotene, while a consistent decrease between 1990 and 2004 was observed, with lutein, lycopene and β-carotene showing the greatest reduction. These changes have caused the contribution of provitamin A carotenoids to the total intake also to increase from one-third in 1964 to half in 2004.

As shown, changes in the consumption of specific fruits and vegetables account for most of the variations in the crude total intake and the relative contributions to carotenoid intake. The contribution of watermelon to lycopene intake has shown a consistent increase even though the present level of lycopene intake has returned to that in 1964. Regarding β-cryptoxanthin, intake has significantly increased, to almost double that in the period 1964–1980, which is associated with an increased contribution of tangerine consumption which parallels the decreasing contribution of oranges to β-cryptoxanthin intake. With regard to α- and β-carotene, a significant increase is observed for both, which for α-carotene may be associated with a significant increase in the consumption of carrots relative to other vegetables during this period. For β-carotene, this increase has been less dramatic, a fact that may be related to the greater number of food contributors to β-carotene intake and the decreasing relevance of other important contributors such as tomatoes and green leafy vegetables.

Finally, the modifications in fruit and vegetable consumption during this time have provoked changes in the relative contribution of individual carotenoids within the total diet (Table 2).

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Table 1 Major contributors among fruits and vegetables to Spanish dietary carotenoid intake

	Non-provitamin A carotenoids											
	Lutein				Zeaxanthin				Lycopene			
Item	1964	1980	1990	2004	1964	1980	1990	2004	1964	1980	1990	2004
Green leafy vegetables*	52.1	51.3	45.2	41.1	17.2	20.8	17.0	14.4				
Carrot	0.4	1.8	4.2	5.3								
Green beans	8.3	10.7	10.8	7.8								
Lettuce†	3.2	9.3	8.0	7.8								
Pepper‡	2.9	3.1	3.3	5.3	14.5	19.0	19.1	28.3				
Potato	18.3	9.4	8.5	7.4	42.9	27.1	22.6	18.5				
Tomato	4.8	4.1	4.6	5.1					99.9	79.5	73.0	68.3
Banana	0.2	0.2	0.2	0.3								
Orange	5.2	5.4	7.3	7.2	24.7	31.7	39.3	36.5				
Peach	0.1	0.2	0.4	0.4	0.4	1.3	1.9	2.1	0.1	0.2	0.3	0.2
Tangerine												
Watermelon		0.7	1.1	1.6						20.3	26.8	31.4
Cumulative (%)§	95.4	96.2	93.5	89.4	99.8	99.8	99.8	99.8	100.0	100.0	100.0	100.0
Daily intake (μg per person per day)	534.0	676.3	558.0	380.1	108.7	112.5	100.1	73.0	1039.6	1414.7	1436.6	1162.7
	Provitamin A carotenoids											
	β-Cryptoxanthin				α-Carotene				β-Carotene			
	1964	1980	1990	2004	1964	1980	1990	2004	1964	1980	1990	2004
Green leafy vegetables*									26.6	18.6	10.7	8.1
Carrot					52.3	81.6	91.0	92.1	9.6	35.1	53.8	56.8
Green beans					17.1	6.7	3.2	1.9	3.8	3.5	2.3	1.4
Lettuce†									1.4	2.8	1.6	1.3
Pepper‡	7.3	6.1	4.6	6.3					7.2	5.5	3.9	5.1
Potato									0.8	0.3	0.2	0.1
Tomato									42.1	25.6	18.8	17.4
Banana					17.9	7.5	3.2	3.9	1.6	1.6	0.9	1.2
Orange	88.5	72.3	67.1	57.8	12.5	4.0	2.5	2.0	3.4	2.5	2.2	1.8
Peach	1.0	2.0	2.2	2.2	0.2	0.2	0.1	0.1	0.3	0.6	0.6	0.6
Tangerine	2.4	15.3	22.6	29.4					0.2	1.3	1.7	2.2
Watermelon		3.2	2.4	3.0						0.9	0.9	1.1
Cumulative(%)§	99.2	98.8	98.9	98.6	99.9	100.0	100.0	99.9	96.9	98.1	97.4	96.9
Daily intake (μg per person per day)	205.5	334.5	397.6	312.7	42.2	175.7	306.3	261.0	575.9	1026.7	1303.2	1065.1

* Average between beet and spinach.
† Average between leafy and iceberg varieties.
‡ Average between red and green varieties.
§ The remaining cumulative percentages correspond to the sum of kiwi, lemon, pear, cherry, melon, strawberry, grape, cauliflower, cabbage (red and white), squash, cucumber and onion.

Discussion

The present data provide estimations of the carotenoid intake in the Spanish population over the last 40 years. For this purpose, we used available data on food consumption collected using a comparable methodology, including the representativeness of the sample, the distribution of the food consumption (both in households and outside the home) over the year, and the use of HPLC-determined carotenoid content data in fresh fruit and vegetables commercialised in Spain. However, small differences in the methodology and in the foods categorised at each time point forced us to group some items with similar characteristics and/or carotenoid content in order to make these data comparable over the whole period studied, a fact that may have led to over- or under-estimation of the relative contribution of single foods at a certain time point.

Table 2 Relative contribution (%) to total carotenoid intake (from fresh fruits and vegetables)*

Year	Total carotenoid intake (mg per person per day)	Lutein	Zeaxanthin	β-Cryptoxanthin	Lycopene	α-Carotene	β-Carotene
1964	2.506	21	4	8	42	2	23
1980	3.740	18	3	9	38	5	27
1990	4.102	14	3	10	35	8	32
2004	3.255	12	2	10	36	8	33

* Estimations based on data shown in Table 1. Total carotenoid intake = sum of lutein, zeaxanthin, β-cryptoxanthin, α-carotene and β-carotene.

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Since 1964, a continuous decrease in the consumption of potatoes is observed, with a parallel increase in fruit and vegetable consumption until the decade of 1980–1990. This change has been associated with an increase in total carotenoid intake, although since then (1990) a consistent decrease in the intake of several carotenoids is detected even when the average consumption of fruits and vegetables apparently still fits the World Health Organization recommendations, >400 g per person per day (excluding potatoes)[13]. In this sense, the present data are consistent with previous reports regarding the relatively high consumption of fruit and vegetables in our population, as well as the major fruit and vegetable contributors to carotenoid intake in the Spanish population[6,8,26,27]. Thus, variations in the ranking of fruit and vegetables as sources of individual carotenoids can mostly be attributed to true changes in eating patterns over the period studied.

Crude data for total and individual carotenoid intake are difficult to compare because of the differences in methological approaches (populations studied, assessment methods, foods included, i.e. total diet vs. fresh fruits and vegetables only) as well as in the carotenoid databases used[28]. For example, our estimations for average individual carotenoid intake are lower than the median values reported in the Spanish EPIC (European Prospective Investigation into Cancer and Nutrition) cohort (consumption data for 1992–1996), even when they fall within the 25th–75th percentiles of that distribution[27,29], and those reported in a multicentre European study[8]. These differences may partly relate to the use of total diet rather than fruit and vegetables only (present data) since, for example in the EPIC study, juices and other non-plant foods (i.e. condiments and sauces) contribute about 11–25% to β-carotene, β-cryptoxanthin and lycopene intake[27]. However, this relative contribution does not account for the almost double intake of lycopene, β-cryptoxanthin and β-carotene nor the higher consumption of lutein (only associated with fruit and vegetables consumption) reported in those subjects. Thus, while these results suggest a relative degree of agreement between these studies, they also indicate a higher consumption of fruit and vegetables in the EPIC group than that in the general Spanish population, a fact that is also consistent with the special features of this cohort (i.e. active blood donors). However, it is worth noting that both studies identify basically the same major contributors as well as the relative contribution of provitamin A carotenoids (~50%) to the total carotenoid intake.

An interesting approach for comparison is the relative contribution of each carotenoid to the total carotenoid intake. The rationale is that the relative contribution of each carotenoid has some association with its crude intake, and therefore the intake of its major dietary sources, and provides information for each carotenoid (and food sources) within the context of the total diet. Additionally, carotenoids may interact with each other during absorption, transport, and tissue deposition and metabolism, and thus the relative amount of each class and type of carotenoid within the total diet becomes relevant. In this sense, since each of them may display different biological functions and epidemiological associations, the relative occurrence of each carotenoid within the diet may become relevant from both a mechanistic and a health promotion viewpoint.

In the present study, total and individual fruit and vegetable consumption have changed during the period assessed, leading to changes in the intake of specific carotenoids. For instance, the decrease in green leafy vegetables consumption (from 1980) and the large and continuous decrease in intake of fresh potatoes (~70% in the period 1964–2004) may explain the changes in lutein and zeaxanthin intake, although for the latter the increase in orange and red pepper consumption has maintained the level of intake. Also, the increase in lycopene intake in the period 1980–1990 may be related, at least in part, to the lack of accurate data for watermelon consumption in 1964.

Similarly, these modifications in consumption have caused changes in the relevance of each carotenoid within the total carotenoid intake. As shown, even when the crude (total or individual) carotenoid intake has been maintained or even increased over this period, the relative importance of lutein (and zeaxanthin), and to a lesser extent lycopene, has consistently and increasingly fallen since 1964. In parallel, a continuous increased contribution is observed for α- and β-carotene, and to a lesser extent for β-cryptoxanthin. Moreover, although these observations must be interpreted in relative terms, in fact the relative contribution of some carotenoids within the total diet may be even lower (i.e. lutein) or higher (i.e. β-carotene) because of the contribution of other foods to the total carotenoid intake (i.e. sauces, condiments, juices and fortified foods).

Time trends in carotenoid intake have rarely been assessed in European countries. Nonetheless, changes in major dietary sources of carotenoids (fruits, vegetables and cereals) are known to have occurred in European countries during recent decades[30] which is partly explained by changes in socio-economic, demographic and cultural factors. Short-term variation (over a few years) has been assessed in Denmark where, apparently, the intake pattern of carotenoids had not changed from 1995 to 1997[31]. Similarly, in Spain, a fairly consistent pattern of carotenoid intake in relative terms (see Table 2) from fresh fruit and vegetables is observed in the last decade (1991–2004) (Granado *et al.*[6] and present data), although this is different for data estimated over a longer time frame, i.e. 1964–1980–2004 (present data).

Southern European countries (e.g. Greece, Italy, Portugal and Spain) consume greater amounts of fruits

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and vegetables than Northern countries (e.g. the UK, Ireland and the Scandinavian countries)[26] and, consistently, a North–South European gradient for the intake of some carotenoids[6,8,32] and serum concentrations[33] has been reported. Assuming the healthy benefits associated with 'Mediterranean-type diets' (i.e. high in fruit and vegetables), the health-promoting effects of these dietary patterns have been related, among others, to carotenoids other than β-carotene such as lutein (and zeaxanthin), β-cryptoxanthin and total xanthophylls[32,33]. However, market globalisation, demographic factors and socio-economic changes are modulating both the availability of foods and food choices, and consumption in European countries. Thus, the current decreasing trend in both the crude intake and the relative contribution of xanthophylls within the diet observed in the present study may be indicative of true ongoing changes in the Mediterranean-type food habits in our population.

In conclusion, based on the present data, an effort should be made to increase fruit and vegetable consumption in our population to improve carotenoid intake, at least to the levels observed a decade ago. Moreover, because of the potential health benefits of lutein and zeaxanthin, and β-cryptoxanthin in several prevalent age-related conditions, i.e. age-related macular degeneration and bone health, respectively, specific food- and carotenoid-targeted nutritional programmes should be encouraged on a population basis.

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