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Original

Software application for the calculation of dietary intake of individual carotenoids and of its contribution to vitamin A intake

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Abstract

Introduction: The software applications utilized to assess dietary intake usually focus on macro- and micronutrients, but not on other components of the diet with potential beneficial effects on health, which include the carotenoids. The degree to which each carotenoid exerts diverse biological activities differs and, thus, it is in our interest to know their composition in foods on an individual basis.

Objective: To develop a software application with individualized data on carotenoids that enables the calculation of their dietary intake and consultation of the contents of these compounds in foods.

Material and methods: Software application developed with Java 7, which includes a database of the carotenoids (lutein, zeaxanthin, lycopene, β-cryptoxanthin, α-carotene and β-carotene) in foods (including those that are major contributors to carotenoid intake in Europe), generated by HPLC. The variables include those relative to the foods, subjects and diets that are necessary to provide accurate information on the content of carotenoids in foods and to enable the calculation of their intake.

Results: The software application enables the calculation of the dietary intake of individual carotenoids from 128 foods (raw and cooked), and their contribution to vitamin A intake, in the two forms employed at the present time: retinol equivalents (RE) and retinol activity equivalents (RAE).

Conclusions: This software application is a dynamic, specific and accurate tool for the consultation of carotenoid concentrations in foods and the calculation of their intake, aspects that are essential in research studies on diet and health.

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APLICACIÓN INFORMÁTICA PARA EL CÁLCULO DE LA INGESTA DIETÉTICA INDIVIDUALIZADA DE CAROTENOIDES Y DE SU CONTRIBUCIÓN A LA INGESTA DE VITAMINA A

Resumen

Introducción: Las aplicaciones informáticas utilizadas para valorar la ingesta dietética suelen centrarse en macro y micronutrientes, pero no en otros componentes de la dieta con potenciales efectos beneficiosos sobre la salud, entre los que están los carotenoides. El grado en que cada carotenoide ejerce diversas actividades biológicas es diferente y por tanto, interesa utilizar datos de su composición en alimentos de forma individualizada.

Objetivo: Elaborar una aplicación informática con datos individualizados de carotenoides que permita el cálculo de su ingesta dietética y la consulta del contenido de estos compuestos en los alimentos.

Material y métodos: Aplicación informática desarrollada con Java 7, que incluye una base de datos de carotenoides (luteína, zeaxantina, licopeno, β-criptoxantina, α-caroteno y β-caroteno) en alimentos (incluyendo aquellos que son principales contribuyentes a la ingesta de carotenoides en Europa), generados por HPLC. Se incluyen las variables relativas a los alimentos, sujetos y dietas, que son necesarias para una correcta información del contenido de carotenoides en alimentos y para el cálculo de su ingesta.

Resultados: La aplicación informática permite calcular la ingesta dietética individualizada de carotenoides, a partir de 128 alimentos (crudos y cocinados) y su contribución a la ingesta de vitamina A, en las dos formas utilizadas actualmente, equivalentes de retinol y equivalentes de actividad de retinol.

Conclusiones: Con esta aplicación informática se facilita la consulta de concentraciones de carotenoides en alimentos y el cálculo de su ingesta de forma ágil, específica y precisa, aspectos imprescindibles en los estudios de investigación sobre dieta y salud.

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Palabras clave: *Aplicación informática. Carotenoides. Vitamina A. Registros dietéticos. Frutas y hortalizas.*

Introduction

The assessment of dietary intake is carried out by means of dietary data collection, using food intake records, for the purpose of obtaining manageable and interpretable data on the intake of macronutrients, micronutrients and other compounds that are potentially beneficial to health (e.g. carotenoids, polyphenols, etc.). This intake assessment is one of the mainstays, together with the recording of biochemical and anthropometric parameters, for the evaluation of the nutritional status, which is essential for the implementation and follow-up of health strategies on the individual basis or in public health.

The transformation of foods into nutrients is performed using food composition tables, classically completed by hand and, at the present time, employing spreadsheets developed by research teams for their own use or by means of software applications, some of which are commercially available.[1-3] These tables generally contain macronutrient and micronutrient composition data, but do not specify the carotenoids, despite the relevance of these substances in studies that have related diet to health for years, both for their provitamin A activity and for other biological activities such as antioxidant activity, potentiation of immune function, and their relationship to different diseases (lutein and improved visual function;[4-6] lycopene and cardiovascular health).[7-9] On the other hand, knowledge of the concentration of each carotenoid in foods is highly interesting since de degree to which they exert their biological activities differs from one carotenoid to another,[10,11] and the manner in which they express their contribution to vitamin A intake can also be calculated in different ways. Thus, and on the basis of previous reports by our group concerning the carotenoid content of,[12-14] and on carotenoid intake in the Spanish and European population,[15] our aim was to develop a software application with individualized data on carotenoids that makes it possible to consult the content of these compounds in foods, as well as to calculate their dietary intake, in order to enable the performance of more reliable and accurate studies on diet and health.

Material and methods

The software application was developed with Java 7 (v. 7) using a database of carotenoid content in foods previously published by our group,[16] which provides the levels of the carotenoids usually assessed in the context of diet and health: lutein, zeaxanthin, lycopene, β-cryptoxanthin, α-carotene and β-carotene. In addition to these carotenoids, the software application makes it possible to include data on the following: γ-carotene, α-cryptoxanthin, phytoene, phytofluene, violaxanthin, neoxanthin, neurosporene, capsanthin, capsorubin, antheraxanthin, lactucaxanthin, canthaxanthin, astaxanthin and echinenone. The foods included, nearly exclusively from the plant kingdom, are the major contributors to the intake of carotenoids in Europe.[15,17,18]

In the software application, we introduced different types of variables relative to the foods, the subjects and their diets, all of which are necessary to provide accurate information on the content of carotenoids in foods and for the calculation of their intake (fig. 1). The description of the foods includes the common name, scientific name, color (reddish-orange, green, yellowish-white), whether it is of plant or animal origin, the food group to which it belongs according to the food composition tables of Moreiras et al.,[19] the edible portion (EP), the literature reference, the concentration of each carotenoid and the contribution of carotenoids in foods to vitamin A intake.

The article presenting the database included in the software application does not provide information on the EP of the foods and, thus, this datum has been taken from original articles published by our group,[12-14] and the foods for which data have been compiled were assigned the EP indicated in the food composition tables of Moreiras et al.[19] The EP of the cooked foods is 100 because the nonedible portion is discarded prior to cooking.

The contribution of each food to vitamin A intake is expressed in the two forms currently used: retinol equivalents (RE) and retinol activity equivalents (RAE).[19,20]

RE (µg/day) = retinol + (β-carotene/6) + (α-carotene/12) + (β-cryptoxanthin/12).
RAE (µg/day) = retinol + (β-carotene/12) + (α-carotene/24) + (β-cryptoxanthin/24).

Concerning the subjects and their diets, the variables considered for the software application are those of interest for the evaluation of nutritional status. With respect to the subjects, we consider the sex, age, body weight, height and body mass index. With regard to the diets, we take into account the day the record is made (the date and whether it is a holiday or a working day), the type of meal (breakfast, midmorning snack, midday meal, midafternoon snack, dinner and others), the food and the amount consumed (weight in grams), which can be established on the basis of the weights of the Spanish portions indicated in the literature.[19]

The reports generated by the application provide information on the intake of individual and total carotenoids, as well as the intake of those grouped as follows: the carotenes (β-carotene, α-carotene, γ-
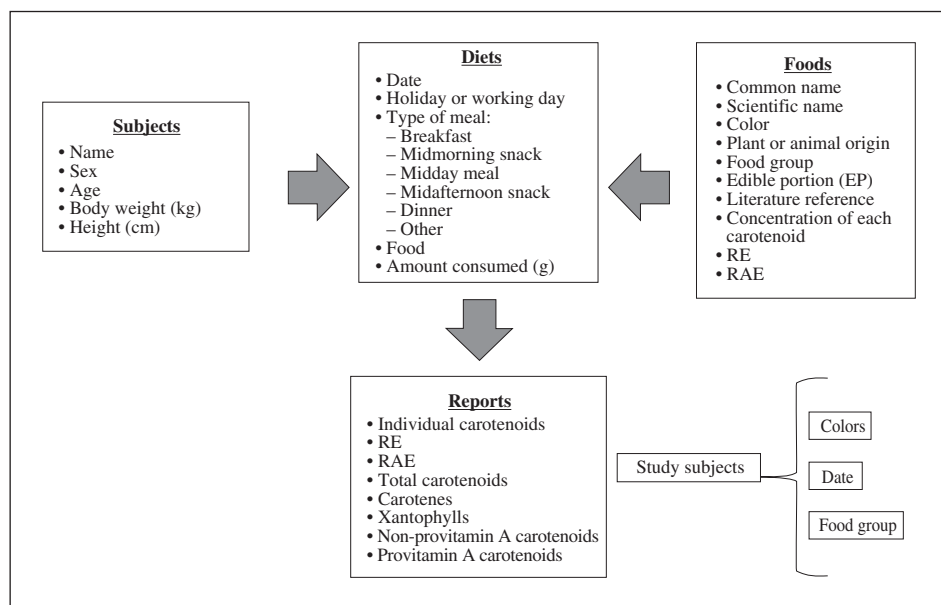
Fig. 1.—Software application diagram.

carotene, lycopene, phytoene, phytofluene and neurosporene), the xanthophylls (lutein, zeaxanthin, β-cryptoxanthin, α-cryptoxanthin, neoxanthin, violaxanthin, capsanthin, capsorubin, antheraxanthin, lactucaxanthin, canthaxanthin, astaxanthin and echinenone), the provitamin A carotenoids (β-carotene, α-carotene, γ-carotene, α-cryptoxanthin, β-cryptoxanthin and echinenone) and the non-provitamin A carotenoids (lutein, zeaxanthin, lycopene, phytoene, phytofluene, violaxanthin, neoxanthin, neurosporene, capsanthin, capsorubin, antheraxanthin, lactucaxanthin, canthaxanthin and astaxanthin).

Results

The application offers three screens with information relative to the foods, the subjects and the diets. In the food screen, we can consult the carotenoid content in the foods and incorporate data on new foods. In the other two screens, with data on the subjects and their diets, we can calculate the dietary carotenoid intake and its contribution to vitamin A intake, and issue reports with the results.

At the present time, the food screen (fig. 2) contains data on the concentrations of six carotenoids (lutein, zeaxanthin, β-cryptoxanthin, lycopene, α-carotene and β-carotene) and the vitamin A content, expressed in RE and RAE, of 128 foods that can be edited. This means that the database can be enlarged over time by adding both new foods and updated data on carotenoid concentrations.

The dietary carotenoid intake is calculated using the subject and diet screens (fig. 3). In the subject screen, the user enters the data relative to age, sex, body weight and height. The application permits the simultaneous enrollment of a subject in different studies, utilizing the corresponding study code which, together with the code automatically assigned upon introduction of the subject's data (ID), enables his or her identification.

The diet records include the date of each record, indicating whether it is a holiday or a working day. For each day recorded, the foods are introduced taking into account the type of meal (presented as a dropdown menu) in which they have been consumed, defined as breakfast, midmorning snack, midday meal, midafternoon snack, dinner and others. In another dropdown menu, corresponding to foods, the user marks the food consumed and enters the amount in grams. When the food is ingested raw, the purchase weight is introduced and the application, using the EP, transforms it into the net amount consumed. In addition to the EP for raw items, the list of foods provides data on certain cooked foods and, for them, the weight indicated by the user should represent the amount consumed, as the EP is 100. The software application does not permit the entry of the same type of food twice on the same date and meal. Thus, if a food is present in more than one dish in a given meal, the total sum in grams has to be introduced.

The reports with the data on the diets of the subjects (identified by means of the study code and ID) are generated in Excel in the "report" file once a study is selected from the dropdown menu of the main screen. This generates three reports on carotenoid intake: foods consumed according to their color; the food groups; and the dates of consumption (fig. 4).

The report of carotenoid intake according to "colors" has a tab for each of the colors under which the foods consumed on the recorded days are grouped. Each tab opens to the user data on the mean intake of individual and total carotenoids provided by each group of foods, identified by their color, and of these carotenoids divided into the groups of carotenes, xanthophylls, non-provitamin A carotenoids and
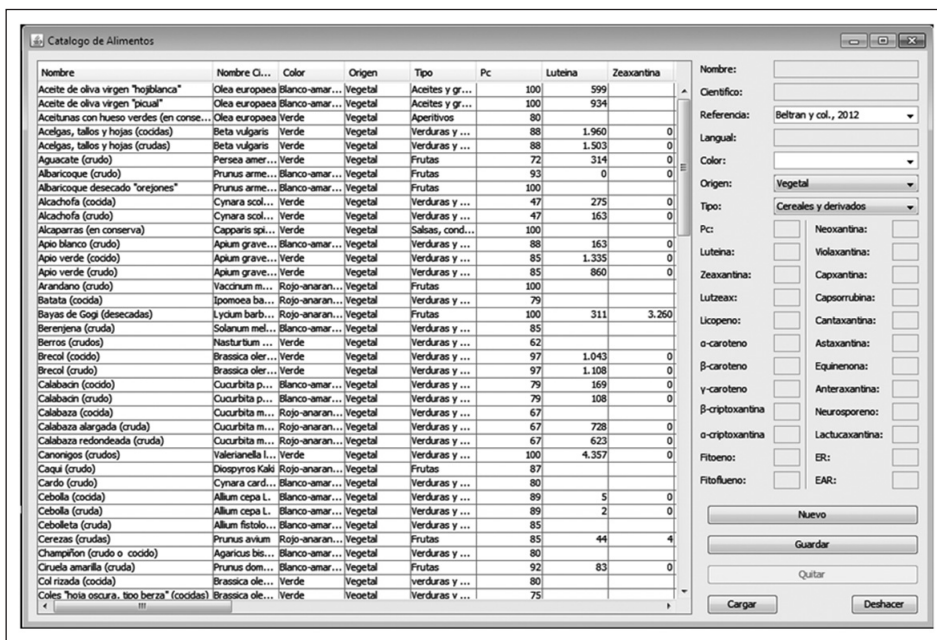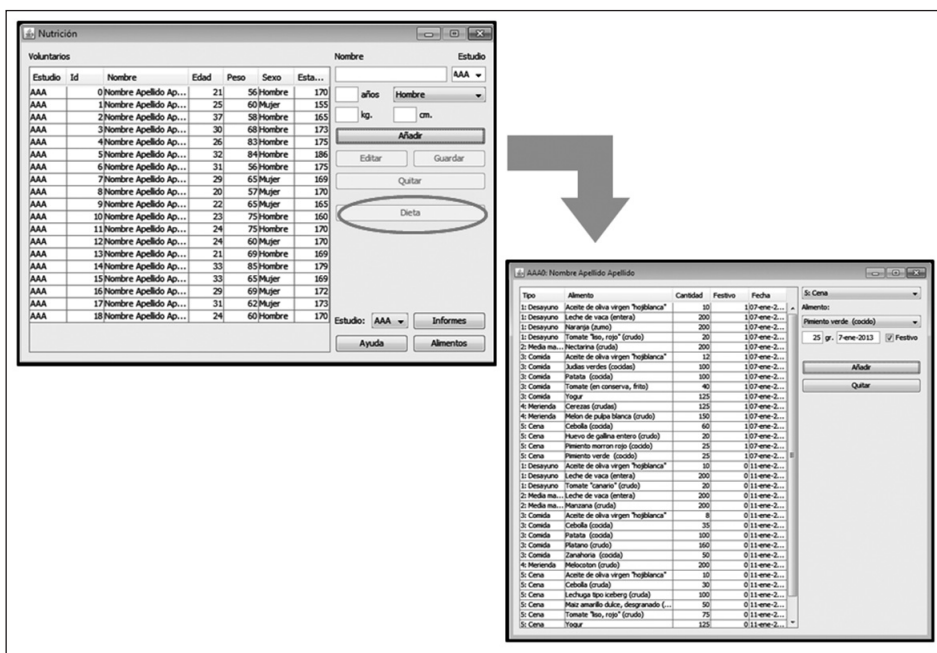
Fig. 2.—Food screen.

Fig. 3.—Subject screen and diet records screen.

provitamin A carotenoids, as well as their contribution to vitamin A intake expressed in RE and RAE. This structure is also employed in the report corresponding to the food groups.

The date report presents two types of tabs: a first set designated by the word "day" and a number that corresponds to the chronological order according to the date of the record. A "day" tab is generated for every day recorded. Each tab opens to the intake, for each type of meal, of individual and total carotenoids, and of these carotenoids divided into the groups of carotenes, xanthophylls, non-provitamin A carotenoids and provitamin A carotenoids, as well as their contribution

to vitamin A intake expressed in RE and RAE, on that record date. The last tab will always be that labeled "Mean of Dates", and shows the mean intake of each volunteer corresponding to the above mentioned variables, based on the data obtained from all the days entered.

Discussion

The software applications employed to assess dietary intake usually focus on the macro- and micronutrients (vitamins and minerals), but not on
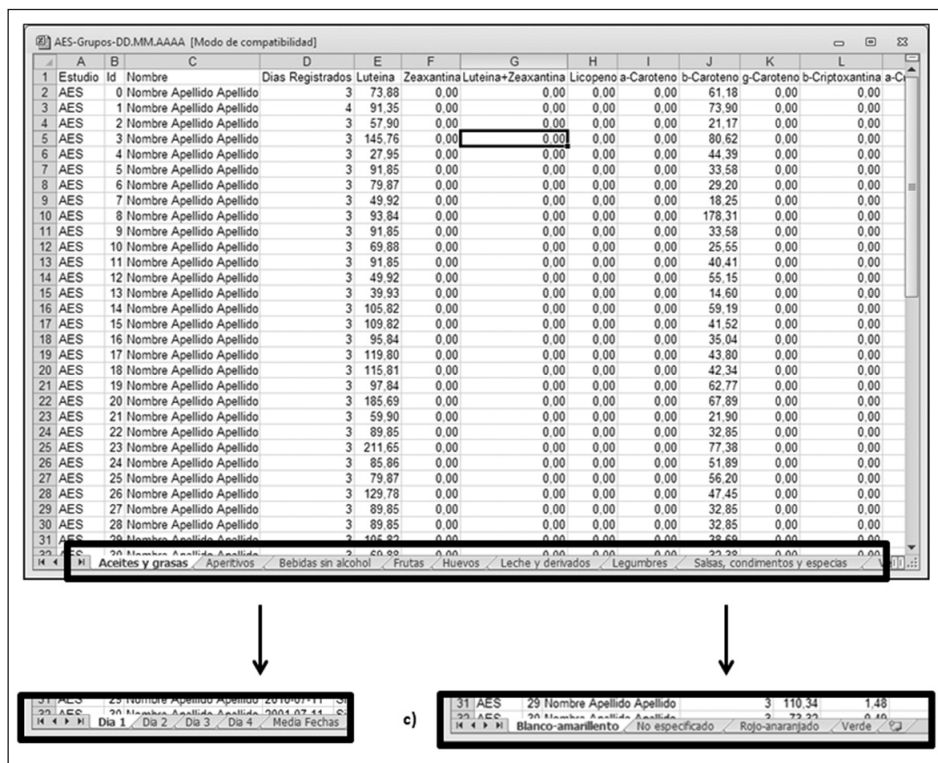
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Fig. 4.—Reports generated by the application: a) Food groups report; b) Date report; c) Colors report.

other components of the diet with potential beneficial effects on health. These compounds are dealt with little or not at all in the food composition tables (e.g. Instituto de Nutrición de Centroamérica y Panamá (INCAP), 2012) (FAO; LATINFOODS, 2009)[21,22] that are sources of data for these applications. Of the tables that include information on carotenoids, very few provide it on an individual basis.[23,24] They generally show data only on the content in β-carotene[25], on the three carotenoids with provitamin A activity expressed jointly[19] or on the vitamin A content expressed as RE[19,22,26] or as RAE.[21,23]

To our knowledge, there is only one software application for the calculation of dietary intake that provides data on carotenoids,[2] using data generated by our group,[12] which we have also used for our application. Moreover, we have included additional data, some from our own analyses, while others were compiled on the basis of well-defined criteria.[16] The foods included are consumed both in Spain[17, 18] and in other European countries.[15] The data on carotenoids included in the application were obtained by high performance liquid chromatography (HPLC), the majority in analyses performed by our group[12-14] using an analytical procedure that is considered to be highly acceptable.[24] For nearly all the foods included in our application, data on lutein and zeaxanthin are provided separately, an approach that is still uncommon in the literature.

The carotenoids for which the software application offers the greatest body of data are those that are found in the largest amounts in human blood and, thus, have been widely studied in the context of diet and health: β-carotene, α-carotene and β-cryptoxanthin (all three with provitamin A activity) and lutein, zeaxanthin and lycopene (without provitamin A activity). However, in the diet, we usually consume more than 40 and, although they do not reach the blood in appreciable amounts, they may have relevant biological activity in other tissues, for example, in the intestines (e.g. neoxanthin, violaxanthin, γ-carotene, phytoene and phytofluene).[27] Thus, these carotenoids have been included in the software application, together with others present in plants widely consumed by the Spanish population (e.g. capsanthin and capsorubin in peppers, lactucaxanthin in lettuce and cucurbitaxanthin in edible gourds), which could be of interest in the future in different branches of research such as health care or ecosystems.

The fact that this software application has a screen with food data constitutes an advantage with respect to other applications used in nutritional evaluation, as it makes it possible to continue to update the information. On the other hand, although there are food composition databases on the web that are updated periodically,[23,25] we have found no applications that incorporate them for the purpose of assessing nutritional status. The consultation of this screen can be useful in different settings such the clinical, agronomic and research sectors. In the clinical setting, it is of interest both for drafting dietary recommendations that make it possible to reach certain levels of vitamin A intake in the general population and for designing personalized diets. It is also a tool for calculating the contribution of each food to vitamin A intake based on the individual content of each carotenoid, either by means of the usual expressions currently in use (RE or RAE), or by any

future expression. Both in the clinical setting and in the research field, it is interesting for us to know specific facts on certain carotenoids that are associated with a reduction of the risk of different diseases, such as lutein and zeaxanthin relative to the risk of age-related macular degeneration[4-6] or lycopene relative to a lower risk of cardiovascular disease,[7-9] which can be of interest for specific subjects or for the performance of intervention studies. Finally, in the agronomic setting, the identification of varieties with a higher content in carotenoids with provitamin A activity or in other carotenoids may be of interest to promote their cultivation or their utilization in the food and agricultural industry.[28] For all these reasons, our aim is to make our software application on carotenoids available on the internet in the near future for the purpose of extending the scope of this work.

The majority of the foods included are vegetables and fruits since they are the major contributors to carotenoid intake. However, others, like dairy products, olive oil and eggs, have been included because, depending on the amounts consumed, they can influence total carotenoid intake. For each food, the common name and scientific name are provided to facilitate their identification, as is the color, since it is usually associated with a given carotenoid profile in the food and is the aspect referred to in dietary recommendations.[29]

For the proper assessment of the carotenoid status of the subjects, we introduced into the application those variables for which differences in their intake or serum concentration have been reported, such as sex and age,[30,31] and others such as body weight and height for the purpose of the classification, and study, of the individuals according to their weight status (normal, overweight and obese), which also influences, in some cases, the serum levels of certain carotenoids, as is the case of lutein.[32] With respect to the diet, since it can be recorded by means of different types of dietary surveys, such as 24-hour recalls, 3-day or 7-day diet diaries, etc., or even surveys repeated over time,[19] the software application is flexible in terms of the number of days reported. It also makes it possible to differentiate between holidays and working days, a datum to be taken into account in order to obtain a true representation of the overall diet of the subject, as meals usually differ depending on the routine of a given day.[33,34]

With respect to the amounts consumed, the software application allows them to be entered in grams, a circumstance that increases the flexibility for use with different dietary surveys, such as those that record the weights of the foods consumed. It also permits greater accuracy, as it does not consider portions of the same size for every type of sample population.

Finally, the fact that the application differentiates the type of meal (breakfast, midmorning snack, midday meal, midafternoon snack, dinner and others) in which a food has been consumed enables us to obtain an idea of the eating habits of the study population, an aspect that is highly useful for evaluations in the clinical or public health setting because it allows us to issue recommendations in accordance with the established habits of a given individual or population.

The calculations of dietary intake are generated in different reports for a given study, according to the characteristics of the food (color or group) and the customary diet of the individual (dates), and all of them provide the data on individual and total carotenoid intake, as well as the intake of those having provitamin A activity, those without provitamin A activity, the carotenes and the xanthophylls. The data is presented in Excel format, which is compatible with most statistical software packages, for the subsequent analysis of the results. The assessment of dietary intake of carotenoids grouped as carotenes and as xanthophylls may be of interest since the chemical structure determines the physicochemical properties (e.g. polarity, solubility) of these compounds and, thus, their greater or lesser accessibility to different tissues and the degree to which they exert certain biological activities.[35]

This software application for our carotenoid database facilitates the consultation of the carotenoid concentrations in foods consumed by the Spanish population, as well as the management of data of each subject and the calculation of their intake of individual carotenoids in a dynamic, specific and accurate way. All of these aspects are essential in studies on diet and health, both relative to the provitamin A activity exhibited by some of them and with respect to other biological activities exerted to a greater or lesser degree by all the carotenoids, and that have potential beneficial effects on human health.

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