A COMPREHENSIVE DATABASE OF CAROTENOID CONTENTS IN IBERO-AMERICAN FOODS. A VALUABLE TOOL IN THE CONTEXT OF FUNCTIONAL FOODS AND THE ESTABLISHMENT OF RECOMMENDED INTAKES OF BIOACTIVES

M. Graça Dias[1]*, B. Olmedilla-Alonso[2], D. Hornero-Méndez[3], A. Z. Mercadante[4], C. Osorio[5], L. Vargas-Murga[6], A. J. Meléndez-Martínez[7]

Affiliations:

[1]Food and Nutrition Department, National Institute of Health Doutor Ricardo Jorge, IP, Av. Padre Cruz, 1649-016 Lisboa, Portugal

[2]Institute of Food Science, Technology and Nutrition (ICTAN). Consejo Superior de Investigaciones Científicas (CSIC). C/ José Antonio Novais, 10. 28040-Madrid, Spain.

[3]Departament of Food Phytochemistry, Instituto de la Grasa (CSIC). Campus Universidad Pablo de Olavide, Edificio 46. Ctra. de Utrera, Km 1, 41013 Seville, Spain.

[4]Department of Food Science, Faculty of Food Engineering, University of Campinas (UNICAMP), 13082-862 Campinas, Brazil

[5]Departamento de Química, AA 14490, Universidad Nacional de Colombia-Sede Bogotá, Bogotá, Colombia

[6]Biothani Europe S.L. Can Lleganya, Sant Feliu de Buixalleu (Catalonia), Spain

[7]Food Colour & Quality Laboratory, Area of Nutrition & Food Science, Universidad de Sevilla, 41012 Seville, Spain

* Corresponding author

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Abstract

Foods that are commonly consumed in the diet are considered to provide more than 40 different carotenoids. However, the content in carotenoids varies considerably both in qualitative and quantitative terms as a consequence of different genotypes, climatic conditions of the production area and agronomic factors, among others. In this paper, analytical data, obtained by HPLC or UHPLC, of carotenoids in fruits and vegetables produced in Ibero-America have been compiled from peer-reviewed journals, organized in food categories and documented in relation to the sampling and analytical quality system used. In addition to common products of the diet of the Ibero-American countries, other wild or little used fruit and vegetables have been included with the aim of contributing to promote and to value species and local varieties. The importance of the commodities containing carotenoids in food, health, agriculture and biodiversity, and the need of their preservation, was evidenced in this work namely by the large differences in carotenoid content related to the locals of production and varieties, and the high levels of carotenoids in native fruits and vegetables. The contribution of these compounds to meet the needs of vitamin A as well as the necessity of establishing recommendation for the daily intakes of theses bioactive compounds were also discussed.

1. Introduction

Carotenoids are considered the most widely distributed pigments in nature.[1] More than 700 different carotenoids have been identified so far,[2] in a wide range of different natural environments, such as in the vegetable kingdom, depth of the oceans, glaciers, hot springs, and salt ponds, among others.[3]

These compounds can be synthesized by photosynthetic organisms (plants, algae, photosynthetic bacteria) as well as by some fungi and non-photosynthetic bacteria. They are also present in a wide variety of animals, which obtain them from the diet. Animals are able to metabolize them despite cannot synthesize carotenoids *de novo*.[4,5] Exceptions to this long-standing rule have recently came out after the analysis of the carotenoid profile and genome in pea aphids (*Acyrthosiphon pisum*), green peach aphids (*Myzus persicae*), and the two-spotted spider mite (*Tetranychus urticae*). These invertebrates are capable of synthesizing carotenoids probably due to a horizontal transfer of biosynthesis genes from fungi into their genome.[6,7]

Carotenoids are known to be involved in many processes in nature, hence they can be considered as very versatile secondary metabolites: light harvesting, photoprotection through singlet oxygen quenching and non-photochemical quenching (xanthophylls cycle), vision, communication between or within species through colour, protection against oxidants, modulation of the properties of membranes, fertility, and reproduction.[8]

Besides, carotenoids can be metabolized into a series of compounds involved in important actions and functions. For example, retinoids (vitamin A) or norisoprenoids (potent aromatic compounds such as, safranal, *β*-ionone, *β*-damascenone, among others), the phytohormone abscisic acid (involved in senescence related processes, the latency of seeds, and so on), or trisporic acid (a stimulant of carotenoid production in certain fungi).[8] Moreover, "new" carotenoid metabolites are attracting much attention. For example, the strigolactones, phytohormones involved in the inhibition of shoot branching, the establishment of arbuscular mycorrhizae, and the germination of parasitic weeds, among other processes.[9-12] Similarly, carotenoid metabolites formed in animals, other than vitamin A retinoids (*e.g*. apo-lycopenoids) are being paid much attention as they may be biologically active and provide health benefits.[13-15] Apart from the role of some carotenoids as precursors of vitamin A, there is a large body of evidence indicating that they may provide health benefits. In summary, it can be stated that carotenoids and their derivatives are involved in a wide variety of actions and are essential for life on Earth and that their relevance in ecology, agro-food industry, health, and other fields is unarguable.

Food carotenoids have attracted the interest of many researchers and their distribution and levels have been extensively studied in different matrices, because a carotenoid-rich diet is frequently associated with a lower risk of developing a series of diseases. Thus, in recent decades, the interest for carotenoids by pharmaceutical and food industries, especially in relation to human health, have grown considerably.

Diets with adequate intakes of carotenoid-rich foods may protect against non-communicable diseases such as, certain cancers,[16] especially prostate and digestive-tract tumours,[17] cardiovascular diseases,[18] diabetes,[19,20] and eye diseases[21,22]. More information about the possible roles of carotenoids in nutrition and health can be found in two dedicated books.[23,24]

About 40 different carotenoids are commonly found in the foods present in our diet,[25] including carotenes (*e.g. β*-carotene, *α*-carotene, lycopene), and xanthophylls (*e.g. β*-

cryptoxanthin, lutein, zeaxanthin). However, food carotenoid composition is very complex and varies both qualitatively and quantitatively.

Typical dietary carotenoids such as, lycopene, *β*-carotene, *β*-cryptoxanthin, lutein, and zeaxanthin exhibit *in vitro* antioxidant capacity, although it is difficult the extrapolation of these data to *in vivo* health benefits.[26] Between the different groups of the so-called phytochemicals, carotenoids are the only one that comprises some compounds to which a specific nutrient function can be attributed. The human body has the capacity to transform some of them in the essential micro-nutrient to human life, the well-known vitamin A. Two forms of vitamin A are available in the human diet: preformed vitamin A (retinol), and provitamin A carotenoids. Carotenoids that could be metabolized by human body into vitamin A are those which structure has at least one unsubstituted *β*-ring and a polyene chain of 11 carbon atoms. Traditionally, *β*-carotene is considered the most important provitamin A carotenoid. It could theoretically originate two retinol molecules due to its chemical structure. Other examples of provitamin A carotenoids are *α*-carotene and *β*-cryptoxanthin. Both provitamin A and preformed vitamin A must be metabolized intracellularly to retinal and retinoic acid, the active forms of vitamin A, in order to exert the important biological functions of this vitamin.[27]

As it is concluded in several studies, the dietary equivalence of *β*-carotene and retinol varies greatly among individuals,[28] although, some reference values have been established. First, about recommended dietary allowances, the NAS/NRC concluded "that in addition to any expression as international unit activity, vitamin A should also be given in terms of retinol equivalents defined as follows: 1 retinol equivalent (RE) = 1 µg retinol = 6 µg *β*-carotene = 12 µg other carotenoid vitamin A precursors". [29] Later the Institute of Medicine reported that, for dietary provitamin A carotenoids, one µg of retinol activity equivalent (RAE) is equal to one µg all-trans retinol; 12 µg of *β*-carotene; 24 µg of *α*-carotene; and 24 µg of *β*-cryptoxanthin.[30] These figures are in line with the guide published by that Institute where is also stated that the RAE for dietary provitamin A carotenoids in foods is two-fold greater than RE.[31] According to the same document for preformed vitamin A in foods or supplements and for provitamin A carotenoids in supplements, 1 RE = 1 RAE. The studies that support these factors are still very rough conducting to estimates with large confidence intervals.

From another authoritative body FAO /INFOODS, conversion from components with vitamin A activity to vitamin A expressed as RAE, is equal to the sum of retinol plus 1/12 of *β*-carotene plus 1/24 of *α*-carotene plus 1/24 of *β*-cryptoxanthin (all in the same units, µg/100 g edible portion on fresh weight basis), with no mention to isomers or other carotenoids with possible vitamin A activity.[32] As a note in this document it is stated that the conversion factors used can be country-specific, *e.g.* in India the conversion factor for *β*-carotene is 1/8; however, in most countries 1/12 is used. Also, in this document, for the conversion of components with vitamin A activity to vitamin A RE, vitamin A is equal to retinol plus 1/6 of *β*-carotene plus 1/12 of *α*-carotene plus 1/12 of *β*-cryptoxanthin (all in the same units, µg/100 g edible portion on fresh weight basis).

The possible relation between the consumption of carotenoid-containing fruits and vegetables and human health;[23,24,33] the fact that carotenoids vary qualitative and quantitatively from species to species; and that variety, maturity, light intensity, and even soil composition introduce large variations in the carotenoid content, underlines the need for a detailed food identification as well as analytical data quality evaluation in publications related to food carotenoid content (e.g. databases).

2. Carotenoid data in food composition tables/databases

The detailed information about the food chemical composition is compiled, usually by country, in food composition tables or more recently databases. These data are the basis, among other aspects to evaluate nutritional problems, elaborate legislation and policies of nutrition, and study the relationship between diet and health status or diseases of individuals and populations.

The first chemical analysis of food in Europe was made in the middle of 19th century. However, the first food composition tables in the format known today were published, in Europe (Germany) in 1878,[34] and in America in 1896[35]. Thereafter, the United of Kingdom, widely seen as a leader in the field of food composition databases, published *The Composition of Foods*,[36] and in 1949 the Food and Agriculture Organization of the United Nations (FAO) published the first international tables and is still active in this field within the International Network of Food Data Systems (INFOODS) project. More recently, many European Food Composition Databases (FCDBs) have become available online on the Internet, a move influenced, within Europe, by The European food Information Resource Network project (2005-10; EuroFIR) funded by the European Community's 6th Framework Programme.

In addition, some specific databases, by analyte, were developed namely for individual amino acids, fatty acids, vitamin fractions, bioactive compounds (EuroFIR eBASIS), isoflavone database (USA), and Phenol-Explorer (France).[37-39]

The increase in research on the relationship between diet and chronic diseases has led to a greater demand for complete, current and reliable FCDBs, specifically bioactive compounds. Also, increasing international trade has led to a greater need to access data for foods from other countries. In general, traditional FCDBs did not cover carotenoids due to limited resources. In general, these analytes are difficult to determine owing to instability, specific analytical conditions, and the expensive instrumentation required for their analyses. West and Poortvliet published the first work in this field in which the inclusion criteria and data quality evaluation was assessed.[40] More recently, there are some examples of food carotenoid databases in countries such as, Spain, Brazil, USA, Austria, Switzerland, and even at an European level.[41-46]

Similarly, there are studies focused on the evaluation of the carotenoid content of foods in other countries like Luxembourg, Portugal, and Costa Rica, among others.[47-49]

The analytical methods applied to carotenoid research are continuously being improved, leading to more specific and detailed data. Nevertheless, the reliability of a substantial part of current data on food carotenoids still appears questionable. This lack of reliability is due to a large extent to the inherent difficulties of carotenoid analysis, specially their instability (they are sensitive to oxygen, light, temperature, and active surfaces), the high cost of standards, and the availability of few Certified Reference Material with high uncertainty values.

The classical open column chromatographic methods were replaced by high performance liquid chromatography (HPLC) methods due to the many advantages of the latter (such as, higher selectivity, rapidity, automation, and computation of data). Currently, HPLC using C_{18} or C_{30} reversed-phase columns and photodiode array (PDA) spectrophotometric detector is the preferred approach for the separation and quantitative determination of carotenoids in extracts isolated from different matrices. Such detector allows for the recording of the entire UV-Vis spectral range from 190 nm to 800 nm, enabling the extraction of chromatograms at each selected wavelength and monitoring at any moment the absorption spectra. However, these detectors are not appropriate to provide molecular structure information for identification, especially of unknown carotenoids in complex matrices. In this sense, the additional use of other detectors, such as, mass spectrometer (MS) detectors, is encouraged.[50]

The need of the reported data quality assessment is unarguably important, as accurate qualitative and quantitative data on carotenoids are needed to assure proper comparability and traceability. In this sense, food description, component identification, sampling plan (number of samples), and sample analysis data (replicates, analytical standard deviation) should be considered. To our knowledge, there is no food carotenoid database for Ibero-American countries nor documenting data to evaluate their quality is available. Unarguably, the production of such database would be important for many purposes, as commented above.

The objective of this review was to gather quantitative data on carotenoids in fruits and vegetables produced in Ibero-American countries, within the frame of the IBERCAROT network (Ibero-American Science and Technology for Development Program (CYTED)).

2.1. Ibero-American food carotenoids database

Since there are no official references regarding carotenoids, analysis of data reporting documents for vitamins were taking into account. The guidance document for the control of compliance with EU legislation regarding to the setting of tolerances for nutrient values declared in a label, established the rounding guidelines for the nutrient declaration, in nutrition labelling of foods; for vitamins rounding to two significant figures, except for vitamin A to three figures, is recommended.[51] To accomplish this accuracy level, at minimum HPLC methods should be considered. Moreover, to achieve an adequate separation to identify and quantify individual carotenoids in food, at least HPLC methods should be used.

Considering that, as discussed before, there is no current scientific agreement regarding the human body conversion of vitamin A activity-carotenoids into retinol. As possible future changes may arise on the equivalences referred above and other putative positive effects of carotenoids in human health, it is better to quote retinol and individual provitamin A carotenoids in FCDBs, instead of RE or RAE.

3. Material and methods

3.1 Literature search

The literature exploration was conducted using Scopus®, the largest abstract and citation database of peer-reviewed scientific literature, from January 1977 to December 2013. The search terms used were *carotenoid*, *carotene*, *xantophyll, lutein, zeaxanthin, cryptoxanthin,* *lycopene, phytoene, phytofluene, food, vegetable, fruit, diet*, database, Spain, España, Spanish, Portug*, Mexic*, Honduras, Guatemala, Nicaragua, Salvador, Costa Rica, Panama*, Colombia*, Venezuel*, Ecuador, Bolivia*, Brazil*, Peru*, Uruguay*, Argentina*, Chile*, Paraguay*, Cuba*, sarsaparilla, rose, quince, arbutus, palm, berry, olive, chard, avocado, apricot, artichoke, caper, sweet potato, cassava, wolfberry, goji, aubergine, broccoli, pumpkin, squash, plum, cabbage, asparagus, spinach, pea, kiwi, lettuce, maize, corn, pasta, passion*, nectarine, papaya, potato, cucumber, pear, pineapple, plantain, banana, carrot, Clementine, mandarin, citrus, pummel, grapefruit, grape, lemon, kaki, persimmon, loquat*. Two different searches were done, one combining the carotenoids terms with food general terms and with country terms, and another one combining carotenoid terms with fruits and vegetables names and with country terms.

3.2 Inclusion criteria

The scrutinized papers to extract data about carotenoids in food were only from Ibero-American countries in order to compile data from items produced in this region. Analytical data on all carotenoids reported in the selected papers from peer-reviewed journals were collected. The first work about carotenoids separation by liquid chromatography was published by Stewart and Wheaton in 1971.[52] The analytical methods considered to analyze the food items presented were HPLC or ultra HPLC (UHPLC) equipped with spectrophotometric detectors.

3.3 Exclusion criteria

Articles that did not meet the desired criteria were excluded, such as, studies of food items not produced in Ibero-American countries or items not intended for human consumption. Food supplements were also out of the scope of this work. Carotenoid results obtained by analytical methods different from HPLC or UHPLC equipped with spectrophotometric detectors were excluded. Also, carotenoid data quoted only in RE or RAE were discarded.

3.4 Article selection and data extraction

Full-text articles of original research were selected from the abstracts obtained after the initial search. All articles obtained using the descriptors were initially evaluated according to their titles, abstracts, and contents. After the identification of all the studies, a pre-selection analysis was performed based on the exclusion criteria.

In agreement with the international efforts, namely by FAO/INFOODS, to document biodiversity, a key organizing principle in sustainable agroecosystems and considering factors affecting the carotenoid content, the information compiled in this document was organized documenting the scientific name, species, varieties/cultivars/accessions (whenever known) and country of production.[53,54] This is important to take into account to certain extent natural variations in the carotenoid composition and the effects of influencing edapho-climatic factors. Additionally, food descriptors, which are relevant for carotenoid content, such as, colour, with/without peel, cooked/raw, were registered, when they were available.

Measurement units varied according to the study (for instance, mg/kg, mg/g, mg/100 g, and µg/g). Therefore, all values were converted to µg/100 g.[32] All results present in the articles were preferentially based on fresh weights; values based on a dry basis were noted in tables presented in this work, and in the cases water content was not referred in the original articles. The levels of each carotenoid are presented as a range for each study that presented more than one value for the same food source.

The analytical method usually includes extraction and saponification steps before the injection of sample extracts in the LC systems. Saponification is mainly carried out to hydrolyse carotenoid esters and/or to eliminate unwanted lipids and sometimes also chlorophylls. However, although saponification can simplify the chromatograms it can also lead to unwanted modifications of carotenoids and other losses, which can affect significantly the precision and accuracy of the analyses.[55] From the experience of our laboratories, although carotenes may resist very well the saponification process, the more polar xanthophylls could be lost during this step and subsequent washing. In this case, it is very likely that the actual xanthophyll contents were higher than the reported ones. To overcome this problem, some authors[56-58] add an internal standard (*e.g. β*-apo-8'-carotenal, equinenone). The time-consuming step (typically from 30 min to overnight) is another drawback of saponification, which extends the time of analysis and reduce the sample throughput. Therefore, saponification should be included only when it is strictly necessary, i.e., in the analysis of materials containing lipids and carotenol esters, since, frequently, the used HPLC systems separate chlorophylls from the carotenoids under study and without the need to eliminate them. Taking these facts into consideration, results gathered were documented with the indication of whether or not the saponification step was included.

Regarding geometrical isomers (all-*E* and *Z* isomers), they were assigned in this review as stated in the original paper, including *Z* isomers whenever possible, since the differentiation between them can be in certain cases important to better understand their bioavailability and bioactivity.[3,59] Data for quality assessment of each datum collected were gathered, when available. Method validation includes the evaluation of several parameters, namely precision and trueness, being a good indicator of the quality of the data obtained by the addressed methods. Undoubtedly, sampling plan quality, the number of lots used to obtain the analytical sample could be an indicator of the representativeness of the analytical data. Collection of data was done taking into account data quality, assigned by method validation, number of lots and number of replicates used to obtain the reported results.

4. Results and discussion

In this work, to collect original data, more than 80 peer-reviewed papers, published from 1977 to 2013, were evaluated by scientists previously trained on the determination of carotenoids in food matrices. Although the research was done from 1977, the first published works on carotenoid composition of products from Ibero-America were in 1983 by a Brazilian team and in 1992 by a Spanish team. Most of the articles are from the 1990s and 2000s, when questions of the effects of food, and in particular of carotenoids, on health have become relevant. Food items were classified in 17 food groups: aromatic herbs, brassica vegetables, fruit vegetables, legumes, leafy vegetables, bulk, stalk and stem vegetables, non-starchy roots vegetables, vegetables with pods, berry fruits, citrus fruits, pome fruits, stone fruits, tropical and sub-tropical fruits, starchy roots, starchy tubers, cereals, and miscellaneous. This compilation includes all carotenoids reported in each paper. Typically, the food carotenoids traditionally reported in carotenoid databases were six, namely α-carotene, β-carotene, β-cryptoxanthin, lycopene, lutein, and zeaxanthin, which are important in human nutrition due to their biological activities and have been studied and associated with some health benefits. Also, these carotenoids are considered to represent more than 95% of total blood serum carotenoids,[60] and are present in the blood of people from different countries and ethnicities. Data on these carotenoids were collected in **Tables 1** to **17** (without notation by a second number after that number). Other carotenoids, such as the colourless phytoene and phytofluene have not been extensively analyzed and reported, despite they are known to widely occur in consumed foods (i.e. citrus, tomato, and carrots) and are absorbable and present in human tissues and biological fluids.[3] Thus, their absence in the compositional tables could mean that they are not detected or were not determined. They are colourless and absorb maximally in the UV region, unlike virtually all the carotenoids, which are coloured and absorb maximally visible light. Other carotenoids, such as violaxanthin and neoxanthin are quite widespread in foods, although they are not found in plasma, at least at levels comparable to the former eight carotenoids. Data on these and other more rarely analyzed carotenoids or with a narrower distribution were presented in tables with a special notation, a second number after the first (1, 2, 3).

In line with the international efforts for data documentation,[53] **Tables 1** to **17** present not only the carotenoid content but also varieties/cultivars and the country of production, as well as the corresponding reference so that the reader can easily find the original paper. Data collected show up the intra- and inter-species biodiversity, reflected on carotenoid content within species showing differences as high as among species, sometimes up to 1000 times (*e.g.* zeaxanthin in Andean potato varies from lower than the limit of detection until 1048 µg/100 g of edible part). These results emphasize the importance of food identification in scientific publications at least at variety/cultivar/breed level. The observed differences could be the distinction between nutritional adequacy and inadequacy, regarding for example people depending on plant food to satisfy their vitamin A needs. For a food item with an intra-species *β*-carotene variation between 500 and 5000 µg/100 g, the difference between the ingestion of 100 g of the product is the coverage of 10% to 100% of the vitamin A recommended daily dose. Another important issue in food identification is the geographical site of production; changes could be of one order of magnitude.

According to the gathered values for aromatic herbs, *β*-carotene and lutein contents of coriander produced in Brazil were three times higher than those produced in Costa Rica. In the case of broccoli, there were variations between 414 (Spain) and 3300 (Costa Rica) µg/100 g of edible part for *β*-carotene; for lutein there were variations between 140 (Panama) and 900 (Costa Rica) µg/100 g of edible part.

For green leafy vegetables, in cabbage, *β*-carotene variations were between 12.3 and 3600 µg/100 g of edible part from Costa Rica and Portugal, respectively; and in kale 2240 and 6400 µg/100 g of edible part, from Brazil and Portugal, respectively. Lutein variation in the same countries were from 49.6 to 4700 µg/100 g of edible part (cabbage) and from 2869 to 7200 µg/100 g of edible part (kale), respectively. However, there was no general rule, small variations were observed across countries, for instance, lutein contents in watercress was 4280 and 4357 µg/100 g of edible part, in Panama and in Spain, respectively.

Important variations were found for the same species and varieties cultivated in the same country. For example, in Spain, the edible part of Brussels sprouts showed a variation between 77 and 162 µg/100 g, and from 185 to 468 µg/100 g for β-carotene and lutein, respectively; for peppers, the variations ranged between 12200 and 41800 µg/100 g of edible part for *β*-carotene, 24800 and 68400 µg/100 g of edible part for zeaxanthin, and 8400 and 33000 µg/100 g of edible part for *β*-cryptoxanthin. In a study conducted in Portugal[48] considering three tronchuda cabbage landraces, the carotenoid content varied between 0.5 ± 0.1 and 3.6 ± 0.8 mg/100 g for *β*-carotene and between 0.5 ± 0.1 and 4.7 ± 0.9 mg/100 g for lutein. Relating these values with colour the landrace, the lowest carotenoid content has a yellow-blond green colour, contrary to the other samples (medium to dark-green). From the same study, leaves harvested in June, October, and December, from the same kale (var. *galega)* plants presented variations in the carotenoid contents, apparently related to the season of the year and/or the age of the plant. The content of *β*-carotene and lutein in these kale samples roughly doubled between the first (2.6 ± 0.5 mg/100 g and 4 ± 1 mg/100 g, for *β*-carotene and lutein, respectively) and the last (6 ± 1 mg/100 g and 7 ± 2 mg/100 g, for *β*-carotene and lutein, respectively) harvest.

Regarding root vegetables, in particular carrots, considering productions in Panama, Brazil, Costa Rica, Spain, and Mexico, the variations were between 80 and 19769, and between 4313 and 69876 µg/100 g of edible part, for *α*-carotene and *β*-carotene, respectively.

Wide variations were also found in fruits. Regarding lycopene differences, in guava were found values from 1825 (pink) to 7649 (red); in tomato from 1260 to 62273; in peach palm fruit from 100 (light yellow) to 5350 (red); in watermelon from 1600 to 3500; in pitanga from 1400 to 7110; and in papaya from 12 to 4281 (all values expressed as µg/100 g of edible part). For *β*-cryptoxanthin the variations were from 85 to 449 in orange, 30 to 417 in acerola, and 77 to 4097 in papaya (all values expressed as µg/100 g of edible part). For *β*-carotene variations were between 540 and 2486 in acerola, 7600 and 11900 in cactus pear, 400 and 8540 in peach, 580 and 3558 in mango (all values expressed as µg/100 g of edible part). For *α*-carotene the variations were between 30 and 740 µg/100 g of edible part, in peach palm fruit. For lutein the variations were between 70 and 160 in acerola, and 10200 and 18700 in cactus pear (all values expressed as µg/100 g of edible part).

β-Carotene is the most widespread of all carotenoids in foods, either as a minor or major constituent. From the collected values the highest one was for sweet potato, 12700 µg/100 g of edible part; however, for this species a value of 496 µg/100 g of edible part was also obtained.

Zeaxanthin is a minor food constituent, however, it was found in amounts of 8470, 4620, and 0-1048 µg/100 g of edible part of sastra, sapote, and sweet potato, respectively.

Considering carotenes, although *β*-carotene is much more abundant in food than *α*-carotene, their respectively derived xanthophylls, zeaxanthin and lutein, have an inverse relative abundance. Zeaxanthin is present in plant tissues, namely in leaves and green vegetables, at a considerably lower level than lutein which it is usually the predominant carotenoid.

The more frequently encountered epoxycarotenoid in foods is violaxanthin and in slightly lower quantities neoxanthin, followed by antheraxanthin in minor amounts.

Data regarding some less-common or species-specific carotenoids has also been collected in the present study and were included in the database. The most prominent examples were: capsanthin and capsorubin, the predominant pigments of red pepper; crocetin, in saffron; and lactucaxanthin in lettuce.

The results here compilated exemplify to perfection that the carotenoid content of fruits and vegetables, like of other secondary metabolites, is dependent on many factors such as species, varieties (biodiversity), and geographical site of production. The compiled results indicate that it is necessary to define sampling plans for carotenoid analysis during food composition studies, taking into account the production site, the species, and the within-species diversity; and these variables have to be reported along with the corresponding analytical values.

The present effort is a pioneer to compile and disseminate data on carotenoid composition of food, including wild, underutilized, and little-known foods, such contributing to document food biodiversity in Ibero-American countries. The availability of this compilation could assist to promote local species and varieties and also to valorize and maintain its production. Surprisingly, despite the need to keep these FCDBs updated, since foods and analytical methods have changed, the importance of food composition research is not always recognized by funding bodies. However, they are the basis for most quantitative human nutrition research and for the development of food and nutrition policies at national and international levels. Within this context, the present work is aligned with the overcoming of obstacles and future actions needed, that were identified by Gaine and others.[61] Particularly with the provision of accurate food composition data, obtained by previously validated analytical data, and a set of reliable biomarkers of intake. Indeed, much effort has been put in evaluating the quality control of the data here reported and in their curation.

The compilation produced is useful for different users and stakeholders, namely trade, export, legislation, epidemiologists, and other researchers, health professionals, health educators, policy developers, those concerned with production, sustainability, and food security. The specific nutrient function of provitamin A carotenoids is of particular importance for individuals following diets without products of animal origin that should ensure the consumption of pro-vitamin A carotenoid-rich foods, namely deep yellow and green vegetables and fruits.

Most of Latin-American countries are extensive and include territories with different climates and biodiversity. In this sense, it is important to point-out that tropical and subtropical regions have a climate favouring carotenoid biosynthesis and for that reason a remarkable variety of colourful fruits and vegetables. Many of them are unknown for subtropical countries, despite are excellent sources of carotenoids both in qualitative and quantitative terms. This is all the more important when there have been major lifestyle changes in Ibero-American countries, including increased urbanization in many areas, increased reliance on imported food, and neglect of traditional food systems. This work may contribute to avoiding changes in the diet of locally grown and captured foods for processed foods with high fat, sugar and salt content, being considered responsible for the deterioration of health.

5. Future research needs

Despite in most articles on which this review was based, the topic of precision was addressed through the intra-laboratory standard deviation, trueness is rarely assessed. This is ideally evaluated using certified reference materials and inter-laboratory tests. Beyond the high price of these materials, the availability of compositions/forms that resemble the food samples of interest is limited regarding the matrices and carotenoid composition. On the other hand, for reasons of perishability and stability, only cooked forms are available. Regarding inter-laboratory comparisons, currently there is not any known regular programme neither in Europe nor in Latin-America. To this regard it can be openly stated that there is a clear need of evaluating trueness in the carotenoid field to assure data quality and comparison.

There is quite some scientific debate about the pro-vitamin A activity of different geometrical isomers (*cis/trans* or, more correctly, *Z/E*) of carotenoids. In fact, in the IOM recommendations[31] only (all-*E*)-*β*-carotene is considered having 1/12 of the activity of retinol in a mixed diet, based in some controlled human intervention trials. There is no orientation about how to deal with *Z* isomers in such document. Moreover, there is no mention to *β*-carotene or other provitamin A *Z*-isomers in the literature. At present, there are no enough human feeding trials using stable isotopes or other strategies to address this controversial issue in a satisfactory way. *In vitro* and animal studies are helpful in understanding mechanisms, but extrapolations should not be used for mixed human diets and populations that beyond the metabolic disparities differ in vitamin A status. For example, (9*Z*)-*β*-carotene could be on many occasions an artefact formed as a result of analysis, especially in green leafy vegetables. In addition, some quantities, although generally low, of other *Z* isomers of provitamin A carotenoids can be naturally present in foods or formed as a result of industrial processing or cooking.[62,63] Even though there are some studies indicating that all-*E* and *Z* isomers of carotenoids may show important differences in bioavailability and that isomerisation reactions could occur in the human body.[64-66] Further studies and systematic evaluations by authoritative bodies are necessary to shed more light on the vitamin A activity of *Z* isomers of carotenoids.

For an accurate assessment of vitamin A intake, there is a need of reliable data on individual provitamin A carotenoid concentrations in different foods, as well as information on their bioavailability and capacity of conversion of the carotenoids consumed, since it varies depending on the carotenoid and food matrix. At present, in the calculation of the contribution of carotenoids with provitamin A activity to the intake of vitamin A, it is assumed that bioavailability of *β*-carotene is twice the bioavailabilities of *α*-carotene and *β*-

cryptoxanthin, the latter two contributing in the same proportion to the vitamin A intake.[31] However, these contributions of the provitamin A carotenoids to the vitamin A intake are being questioned.[67-69]

Carotenoid safety would be considered, especially with the consumption of *β*-carotene supplements. *β*-Carotene supplementation should not be recommended due to the risk of lung cancer and also gastric cancer at doses of 20-30 mg/day, in smokers and asbestos workers.[70] The unexpected findings of increased lung cancer in *β*-carotene supplemented smokers in the Alpha-Tocopherol/Beta-Carotene Study (ATBC) and Carotene And Retinol Efficacy Trial (CARET) intervention studies have resulted in the need for expanded research efforts to define the mechanism(s) of action of *β*-carotene.[71] High-dose *β*-carotene supplementation in the animal model clearly results in lung pathology with or without smoke exposure, although the pathology is far worse with smoke exposure.[72] Recent survey data as well as laboratory animal studies continue to find an inverse association between *β*-carotene and cancer risk. Because *β*-carotene is the major source of vitamin A for the majority of the world's population, it is critical to define the safe levels of intake from foods and supplements.

Many of the efforts of modern agriculture have been directed to intensify production, with a great success in terms of increasing crops yields. However, this has been accompanied with a dramatic decrease in the number of commercial crops (*e.g.* rice, pea, corn, wheat) and important losses of biodiversity, and consequently some essential food sources of nutrients have been virtually eliminated. However, in recent years, scientists as well as consumers have become more and more aware of the role of quality foods in health and, thus, this has had an impact in the markets. As a result, farmers in general are paying increasingly more attention to the nutritional quality of their products, and in particular, to the presence of health-promoting compounds. More importantly, in developing countries, where there are many nutrition insecure populations, the disappearance of species or the intake of one variety rather than another could be the difference between micronutrient adequacy or micronutrient deficiency.[73] In this context and because biodiversity is essential for food security and nutrition, it is necessary to mitigate the negative impacts of farming systems and practices on biodiversity with relevance for food, namely the variety, and variability of plants. Of particular importance are underutilized food sources, often even wild/undomesticated genotypes, whose composition in terms of compounds with health promoting effects is imperative to study. In this regard, there are examples of non-cultivated species or varieties (such as, sarsaparilla, wild relatives of tomatoes, and tropical fruits, youngs shoots, among others) that are excellent sources of carotenoids.[74-77] To achieve these goals, it is necessary to collect all the data produced by the different scientific communities in different countries and organize them in databases with the appropriate documentation in order to made them available to different communities and used according to different perspectives. Besides databases can help to define priorities in future investigations, namely generation of new data, improvement of the food supplies, plant breeding, and new methods of cultivation, harvesting, and preservation.

More specifically, the data provided in this article are valuable in the context of research dealing with functional foods and the establishment of recommended intakes of dietary bioactive components in general, and carotenoids in particular. This is a highly timely topic due to the interest in these compounds for their contribution to the maintenance of health and decreasing the risk of chronic diseases.[61,74] Indeed, there is a discussion about the convenience of setting up an appropriate framework for the establishment of such recommendations, which would be the basis of public health messages and the labelling of bioactives, as it was pointed out by Wallace and others.[78] In this sense, there is a risk of consolidating dietary patterns poor in fruits and vegetables and therefore in health-promoting bioactives without such recommendations.[61]

In the EU Regulation on the provision of food information to consumers (Regulation (EU) No 1169/2011) the importance of carotenoids in diet is recognized. On section 5 of foods for which the labelling must include one or more additional particulars, it is stated that for "Foods with added phytosterols, phytosterol esters, phytostanols or phytostanol esters" on number (6) "advice the food is to be used as part of a balanced and varied diet including regular consumption of fruit and vegetables to help maintain carotenoid levels".[79] Also, in the same Regulation on annex XIII, the daily reference intake for vitamin A for adults is 800 µg and 15% of this value is considered as a significant amount for labelling purposes, which in this case is 120 µg/100 g. The current trend of the market advocates more transparent sales processes namely in the communication of food information through labelling for consumers to make informed choices, determines the need of the establishment of carotenoid recommend intake.

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Table 1. Carotenoids in aromatic herbs (μg/100 g)

Name	Origin (Country)	Scientific name	SAP (Y/N)	QA	*α*-carotene	*β*-carotene	*β*-cryptoxanthin	lutein	neoxanthin	violaxanthin	crocetin ester*	Ref
Celery	CRI	*Apium graveolens L. var. Dulce*	Y	VM, nl=5, nw=2	168	16200	226	26400^				1
Celery, green	ESP	*Apium graveolens var. dulce*	N	nw=4		570 ± 14		860 ± 17				2
Celery, green, cooked	ESP	*Apium graveolens var. dulce*	N	nw=4	<LD	1109 ± 77	<LD	1335 ± 91				2
Celery, white	ESP	*Apium graveolens var. dulce*	**N**	nw=4	<LD	65 ± 2	<LD	163 ± 10				2
Coriander	CRI	*Coriandrum sativum cv. Mogiano*	Y	VM, nl=5, nw=2		2100	1630	3780^				1
Coriander	BRA	*Coriandrum sativum*	N	nw=4	7100 ± 4200	6600 ± 1800		10400 ± 4400	2800 ± 1700	3800 ± 1700		3
Parsley	BRA	*Petroselinum hortense*	N			7200 ± 900		8700 ± 700	2500 ± 300	5300 ± 600		3
Saffron	ESP	*Crocus sativus L.*	N	nw=50							135±28.8 *trans* 4-GG 71.8±6.6 *trans*-3-Gg 7.2±3.2 *cis*-4-GG 4.5±2.5 *cis*-3-Gg	4

* g/kg; ^ includes zeaxanthin; VM - validated method; nl - number of lots; nw - number of replicates; Y – Yes; N – No; LD - Limit of detection; QA - Quality assessment; SAP - saponification

Table 2. Carotenoids in brassica vegetables (μg/100 g)

Name	OC	Scientific name	Process	SAP (Y/N)	QA	*α*-carotene	*β*-carotene	lutein	zeaxanthin	neoxanthin	violaxanthin	Ref
Broccoli	BRA	*Brassica oleracea*	Boiled	N	nl=15		1890 (1570-2220)	3460 (3110-3960)		740 (670-830)	600 (310-680)	5
Broccoli	BRA	*Brassica oleracea*	Stir-	Y	nl=10		1575	3275		695	455	5

			fried				(1140-2010)	(2760-3790)		(650-740)	(410-500)	
Broccoli	CRI	*Brassica oleracea var. Italica cv. Marathon*	Boiled	Y	VM	24	3300	9000^				1
Broccoli	BRA	*Brassica oleracea var. italica*	Cooked		nl=4, nw=7		1025 (790-1240)	1610 (1310-1930)				6
Broccoli	PAN	*Brassica oleracea (italica)*	Raw	Y	nw=4			140 ± 20	<LD			7
Broccoli	ESP	*Brassica oleracea*	Raw	N	nw=4	<LD	414 ± 20	1108 ± 50	<LD			2
Broccoli	ESP	*Brassica oleracea*	Cooked	N		<LD	450 ± 40	1043	<LD			2
Brussel sprouts	ESP	*Brassica oleracea L.*	Raw		nl=4		77 ± 10*	185 ± 19				8
Brussel sprouts	ESP	*Brassica oleracea L.*	Cooked		nl=4		162 ± 18*	468 ± 36				8
Cabbage	PAN	*Brassica oleracea (viridis)*	Raw	Y	nw=4			250 ± 10	10 ± 10			7
Cabbage	CRI	*Brassica oleracea var. capitata cv. Bronco*	Raw	Y	VM		19.3 12.3*	49.6^				1
Cabbage	ESP	*Brassica oleracea L.*	Raw		nl=4		22 ± 2*	59 ± 2	6 ± 2			8
Cabbage	ESP	*Brassica oleracea L.*	Cooked		nl=4		33 ± 3*	93 ± 20	6 ± 3			8
Cabbage, red	ESP	*Brassica oleracea L.*	Raw		nl=4		3 ± 0.2*	8 ± 2	<LD			8
Cabbage, red	ESP	*Brassica oleracea L.*	Cooked		nl=4		7 ± 1*	23 ± 1	4 ± 1			8
Cabbage, Tronchuda	PRT	*Brassica oleracea L. var. acephala DC*	Raw	N	VM, nl=3, nw=2	<LD	2800 (460–3600)	3300 (520–4700)	<LD			9
Cauliflower	CRI	*Brassica oleracea var. botrytis cv. Snawball*	Boiled	Y	VM		7.95 6.47*	19.1^				1
Cauliflower	ESP	*Brassica oleracea L.*	Raw		nw=4		2 ± 0.2	4 ± 0.4				8
Cauliflower	ESP	*Brassica oleracea L.*	Cooked		nw=4		28 ± 2	15 ± 1	<LD			8

Kale	BRA	*Brassica oleracea*	Stir-fried	Y	nl=15, nw=2	<LD	2240 (240-2280)	2860 (310-3500)		630 (490-790)	530 (280-880)	5
Kale	BRA	*Brassica oleracea cv.Manteiga*	Raw	N	nl=36		3070 (2280-4240)	4440 (3290-5740)		1200 (880-2590)	2050 (1610-4220)	10
Kale	BRA	*Brassica oleracea cv.Manteiga*	Stir-fried	Y	nl=15		2240-2400	2860-3500		490-790	880-280	5
Kale	BRA	*Brassica oleracea var. Acephala (Manteiga)*	Raw	N	nl=10		5400 ± 50	11100 ± 1600	300 ± 200	1800 ± 700		11
Kale	BRA	*Brassica oleracea var. Acephala (Tronchuda)*	Raw	N	nl=10		6000 ± 14	11400 ± 1000	200 ± 100	1900 ± 400		11
Kale	BRA	*Brassica oleracea var acephala*		N	nl=10, nw=10		3800 (3400-4200)	5450 (5200-5700)		2300 (2000-2600)	3450 (2700-4200)	3
Kale, Galega	PRT	*Brassica oleracea L., var. acephala D.C.*	Raw	N	VM, nl=9, nw=2	<LD	4200* (2600-6400)*	5900 (3700-7200)	<LD			9
Mustard greens	PAN	*Brassica juncea*	Raw	Y	nw=4			5380 ± 420	80 ± 10			7

* *E*-isomers; ^ includes zeaxanthin; VM - validated method; nl - number of lots; nw - number of replicates; Y – Yes; N – No; LD - Limit of detection; QA - Quality assessment; SAP – saponification; () - range

Table 3. Carotenoids in fruit vegetables (μg/100 g)

Name	OC	Scientific name	Process	Peel	SAP (Y/N)	QA	*α*-carotene	*β*-carotene	*β*-cryptoxanthin	lycopene	lutein	zeaxanthin	Ref
Cassabanana, yellow	PAN	*Sicana odorífera*			Y						10 ± 10	40 ± 10	7
Cucumber	ESP	*Cucumis sativa L.*	Raw	Without		nw=4		11 ± 1			16 ± 1		8
Cucumber, greenish	CRI	*Cucumis sativus cv. Roxinante*	Raw	Without	Y	VM		12.5 11.1*			51.1^		1
Melon	PAN	*Cucumis melo*			Y	nw=4					30 ± 10	10 ± 10	7

Melon, white	ESP	*Cucumis melo*	Raw	Without	Y	nw=4	<LD	21 ± 5	<LD	<LD	2 ± 0.5	<LD	2
Muskmelon	CRI	*Cucumis melo L. var. cantalupensis cv. Hy-mark*	Raw	Without	Y	VM	44	3600	8	61.9	53^		1
Muskmelon	PAN	*Cucumis melo L. var. cantalupensis cv. Hy-mark*	Raw	Without	Y	VM	44	3600	8	61.9	53^		1
Okra	PAN	*Abelmoschus esculentus*	Raw		Y	nw=4					520 ± 30	10 ± 10	7
Pepper	CHL/MEX	*Capsicum annuum L., var. Ancho*	Dried		Y	nl=2	598 (157-1038)	1527 (1481-1572)	729			454 (258-649) 631.68**	12
Pepper	CHL/MEX	*Capsicum annuum L., var. Guajillo*	Dried		Y	nl=2	302 (86-517)	1153 (1095-1210) 290**	472 (299-644)			213 (127-298) 358**	12
Pepper	CHL/MEX	*Capsicum annuum L., var. Mulato*	Dried		Y	nl=2	416 (216-615)	938 (796-1079) 637.12**	233 (23.9-442)		32.6 (1.45-63.7)	130 (2.17-258) 129.6**	12
Pepper, green	PAN	*Capsium anuumm*	Raw		Y						390 ± 40	ND	7
Pepper, green	ESP	*Capsicum annuum L.*	Raw	Without		nl=8		205-270			341-770		8
Pepper, green	ESP	*Capsicum annuum L.*	Cooked	Without		nl=4		255 ± 10			377 ± 83		8
Pepper, green	ESP	*Capsicum annuum L.*	Raw	Without		nl=6		270 ± 40			770 ± 160		13
Pepper, Jalapeño, green	MEX	*Capsicum annuum L.*		Without		nl=3	146 (9-179)	6374 (381-8576)			836		14
Pepper, orange	PAN	*Capsium annumm*	Raw		Y	nw=4					790 ± 60	6200 ± 880	7

Pepper, red	BRA	*Capsicum annuum L. (F1 Amanda hybrid)*	Raw	Without	Y	nl=5; nw=2		580 ± 60*		750 ± 80*		15
Pepper, red	CRI	*Capsicum annuum cv. Nathalie*	Raw		Y	VM	116	192				1
Pepper, red	PAN	*Capsium annumm*	Raw		Y	nw=4				220 ± 40	440 ± 40	7
Pepper, red	ESP	*Capsicum annuum L. Bola type*	Dried	Without	Y	nl=5; nw=4		14500 (12200-20900)	11900 (8400-17700)		31000 (24800-39900)	16
Pepper, red	ESP	*Capsicum annuum L cult Mana*	Raw	With	Y						197800	17
Pepper, red	ESP	*Capsicum annuum L cult MA1*	Lyophilized	With	Y	nl=5; nw=4		45403 (2556-71951)	47008 (0-60761)	1263 (0-9683)	63589 (0-95379)	17
Pepper, red	ESP	*Capsicum annuum L cult MA3*	Lyophilized	With	Y	nl=5; nw=4		42308 (3127-73669)	47559 (0-95977)	110.83 (0-3305)	32067 (0-66728)	17
Pepper, red	ESP	*Capsicum annuum L cult RN1*	Lyophilized	With	Y	nl=5; nw=4		31750 (2366-41972)	31934 (0-41752)	3200 (0-5875)	56375 (0-67827)	17
Pepper, red	ESP	*Capsicum annuum L cult RN2*	Lyophilized	With	Y	nl=5; nw=4		32412 (2150-48692)	30816 (0-45000)	4906 (0-7596)	49269 (0-71692)	17
Pepper, red	ESP	*Capsicum annuum L cult LR2*	Lyophilized	With	Y	nl=5; nw=4		11217 (4150-109972)	14799 (0-39263)	4005 (0-14047)	30036 (0-63590)	17
Pepper, red	ESP	*Capsicum annuum L cult LR7*	Lyophilized	With	Y	nl=5; nw=4		19289 (1496-32751)	22648 (0-31550)	2129 (0-9309)	47661 (0-56293)	17
Pepper, red	ESP	*Capsicum annuum L cult DN3*	Lyophilized	With	Y	nl=5; nw=4		34212 (2302-65155)	34433 (0-41291)	4495 (0-7113)	65097 (0-135178)	17

Pepper, red	ESP	*Capsicum annuum L cult DN5*	Lyophilized	With	Y	nl=5; nw=4	39987 (4572-68301)	50069 (0-68173)	0 (0-14837)	83500 (0-165010)	17
Pepper, red	ESP	*Capsicum annuum L cult RR1*	Lyophilized	With	Y	nl=5; nw=4	15369 (1701-30414)	17961 (0-23456)	2259 (0-7278)	35556 (0-40570)	17
Pepper, red	ESP	*Capsicum annuum L cult DR6*	Lyophilized	With	Y	nl=5; nw=4	43501 (1380-62352)	33530 (0-63351)	0 (0-6116)	74089 (0-105990)	17
Pepper, red	ESP	*Capsicum annuum L cult MA5*	Lyophilized	With	Y	nl=5; nw=4	45404 (2556-71951)	47009 (0-60761)	1264 (0-9683)	63590 (0-95379)	17
Pepper, red	ESP	*Capsicum annuum L cult MA7*	Lyophilized	With	Y	nl=5; nw=4	42309 (3127-73669)	47560 (0-95977)	110.83 (0-3305)	32068 (0-66728)	17
Pepper, red	ESP	*Capsicum annuum L var Agridulce*	Raw	With	Y	nl=2	5375 (798-9951)	7672	1409 37**	9996 752**	18
Pepper, red	ESP	*Capsicum annuum L var Bola*	Raw	With	Y	nl=2	2876 (623-5128)	3559	795 71**	4030 347**	18
Pepper, red	ESP	*Capsicum annuum L.*	Raw	Without		nl=10	446 (414-478)	225 (199-251)		219 (148-289)	8
Pepper, red	ESP	*Capsicum annuum L.*	Cooked	Without		nl=12	731 (693-768)	307 (243-371)		294 (197-390)	8
Pepper, red, Paprika	ESP	*Capsicum annuum L. Bola type*	Dried	Without	N	nl=5; nw=4	22300 (19700-41800)	20600 (14900-33000)		40000 (34200-68400)	16
Pepper, yellow	BRA	*Capsicum annuum L. (F1 Magali hybrid)*	Raw	Without	Y	nl=5; nw=2	230 ± 80*		780 ± 120*		15
Pepper, yellow	PAN	*Capsium anuumm*	Raw		Y	nw=4			220 ± 20	440 ±60	7
Peruvian cape gooseberry	PAN	*Physalis peruviana*			Y				250 ± 20	40 ± 10	7

Peruvian cape gooseberry	CHL/COL	*Physalis peruviana*	Pulp					388.8 -1460					19
Pumpkin	PRT	*Curcubita pepo L. var. styriaca Greb.*	Raw	With	N	nl=3, nw=3	56.4* (44-65.2)*	232* (186-275)*			49 (<LD-76)		20
Pumpkin (round)	ESP	*Cucurbita maxima*	Raw	without	Y	nw=3	31	188	<LD	<LD	623	<LD	21
Pumpkin (size squash)	ESP	*Cucurbita maxima*	Raw	without	Y	nw=3	53	692	<LD	<LD	728	<LD	21
Pumpkin, orange	CRI	*Cucurbita moschata var. Native*	Boiled		Y	VM	96.7	246 225*		32.3**	902		1
Pumpkins, orange-yellow	BRA	*Cucurbita moschata Duch/ A*	Raw	With	N	nl=10, nw=3	7003 (6706-7299)						22
Squash	PAN	*Cucurbita maxima*	Raw		Y	nw=4					8170 ± 1510	190 ± 30	7
Squash, orange	ARG	*Curcubita moschata*	Without	Without	Y		2300 ± 400	600 ± 100			300 ± 100		23
Squash, yellow	ESP	*Cucurbita pepo L. var. Medellusa, Alef*	Raw	without	Y	nl=8		22 (21-23)	3 (<LD-6)		104 (100-108)		8
Squash, yellow	ESP	*Cucurbita pepo L. var. Medellusa, Alef*	Cooked	without	Y	nl=8		27 (26-28)	6 (<LD-11)		144 (118-169)		8
Tomato	BRA	*Lycopersicon esculentum Cultivar santa cruz*	Raw			nl=10		510 ± 1.1		3110 ± 20.2* 300 ± 2.4**			24
Tomato	BRA	*Lycopersicon esculentum*	Juice			nl=3		200 ± 0.5* 2 ± 0.01**		6160 ± 7.6* 710 ± 5.5**			24

Tomato	BRA	*Lycopersicon esculentum*	Puree			nl=18		415* (300-620)* 170** (100-260)**		12330* (7380-19370)* 975** (360-1800)**			24
Tomato	BRA	*Lycopersicon esculentum*	Paste			nl=12		590* (430-870)* 200** (170-360)**		16440* (15830-18270)* 1500** (830-2090)**			24
Tomato	PAN	*Lycopersicon esculentum*	Raw			nw=4		350 ± 0.8* 100 ± 0.3**		10290±41.4 * 1000 ± 1.6**	340 ± 60	130 ± 20	7
Tomato, red	BRA	*Lycopersicon esculentumcv Carmen*	Raw		N					3540 ± 950	100 ± 20		13
Tomato, red	CRI	*Lycopersicun esculentum cv. Liro 42*	Raw		Y	VM		280 261*		1260 1150*	131^		1
Tomato, red	ESP	*Solanum lycopersicum Mill, common type*	Raw	without		nl=4		494 ± 124		2116 ± 583**	52 ± 12		8
Tomato, red	ESP	*Solanum lycopersicum Mill, Canary islands type*	Raw	without		nl=4		443 ± 37		1604 ± 283**	44 ± 1		8
Tomato, red	ESP	*Solanum lycopersicum Mill, pear type*	Raw	without		nl=4		393 ± 39 3501**		62273 ± 7944**	72 ± 7		8
Tomato, red	PRT	*Lycopersicon esculentum M. var. Lido*	Raw	With	N	VM, nl=12, nw=2	<8	1000 ± 140*	<6	8000 ± 2000**	100 ±17	<8	25
Tomato, red	PRT	*Lycopersicon esculentum M. var. "for salad"*	Raw	With	N	VM, nl=12, nw=2	<8	390 ± 56*	<6	2300 ± 570**	80 ± 15	<8	25

Tomato, red	PRT	*Lycopersicon esculentum M.*	Raw	With	N	nw=3		255* (170-513)*	<LD	8440 (8340-9600) 7875* (6700-9050)*	77.1* (<LD-102)*		20
Watermelon	BRA	*Citrullus lamatus cv. Crimson Sweet*						260 ± 170		3500 ± 200			26
Watermelon, red	CRI	*Citrullus vulgaris cv. Micky-Lee*	Raw	Without	Y	VM		21.9 21.8*		1600*			1
Watermelon, red	ESP	*Citrullus vulgaris cv. Schered*	Raw	Without	N	Nw=3	<LD	62.6	63.2	2489	35.3	<LD	2, 27
Watermelon, red	ESP	*Citrullus vulgaris cv. Schered*	Raw	Without	Y	Nw=3	<LD	77.1 ± 29	62.3 ± 20	2454 ± 319	39.8 ± 13	<LD	2, 27
White bryony, green	ESP	*Bryonia dioica*	Young shoots					6690 (1490-19530)			19130 (6830-36980)		28
Zucchini squash, green	CRI	*Cucurbita pepo L. cv. Caserta*	Boiled		Y	VM					39.9^		1

* *E*-isomers; ** *Z*-isomers; ^ includes zeaxanthin; VM - validated method; nl - number of lots; nw - number of replicates; Y – Yes; N – No; LD - Limit of detection; QA - Quality assessment; SAP – saponification; () - range

Table 3.1. Carotenoids in fruit vegetables (µg/100 g) (cont.)

Name	OC	Scientific name	Processing	Peel	SAP (Y/N)	QA	neoxanthin	violaxanthin	α-cryptoxanthin	capsanthin	capsanthin 5,6-epoxide	Ref
Pepper	CHL/MEX	*Capsicum annuum L., var. Ancho*	Dried		Y	nl=2	212 (18.9 - 406)	545 (<LD - 1090)	199 (0 - 397)	584* (438-729)* 1046** (760-1331)**		12

Pepper	CHL/MEX	*Capsicum annuum L., var. Guajillo*	Dried		Y	nl=2	294 (159 - 429)	446 (<LD - 892)	441 (151 - 730)	692* (533- 852)* 605** (533-676)**		12
Pepper	CHL/MEX	*Capsicum annuum L., var. Mulato*	Dried		Y	nl=2	<LD	1197 (804-1593)	283 (52.1 - 513)	407* (3.62-811)* 364** (8.69-719)**		12
Pepper, green		*Capsicum annuum L.*	Raw	without		nl=6	310 ± 50	460 ± 140				13
Pepper, Jalapeño, green	MEX	*Capsicum annuum L.*		Without		nl=3		13975 (225-15888)				14
Pepper, red	BRA	*Capsicum annuum L. (F1 Amanda hybrid)*	Raw	Without	Y			270 ± 50*		3260 ± 270*		15
Pepper, red	ESP	*Capsicum annuum L. (RR-1)*	Dried	Without	N	nl=5, nw=4				159600 (128100-184200)		16
Pepper, red	ESP	*Capsicum annuum L / cultivar Mana*	Raw		Y					668700		17
Pepper, red	ESP	*Capsicum annuum L / cultivar Numex*	Raw		Y					370500		17
Pepper, red	ESP	*Capsicum annuum L / cultivar Negral*	Raw		Y						61400	17
Pepper, red	ESP	*Capsicum annuum L cult MA1*	Lyophilized		Y	nl=5, nw=4	0 (0 - 3138)	9727 (1351-19435)		371136 (0-799443)	10918 (0-34140)	17
Pepper, red	ESP	*Capsicum annuum L cult MA3*	Lyophilized		Y	nl=5, nw=4	0 (0-4731)	8741 (3707-27282)		258702 (0-414103)	19128 (0-29672)	17

Pepper, red	ESP	*Capsicum annuum L cult RN1*	Lyophilized	Y	nl=5, nw=4	1356 (0-2330)	8321 (2286-33239)		274398 (0-560570)	14966 (0-36605)	17
Pepper, red	ESP	*Capsicum annuum L cult RN2*	Lyophilized	Y	nl=5, nw=4	1102 (0-2445)	8026 (3569-29857)		253445 (0-636308)	14025 (0-33011)	17
Pepper, red	ESP	*Capsicum annuum L cult LR2*	Lyophilized	Y	nl=5, nw=4	483 (0-4485)	6089 (3954-21785)		159486 (0-443535)	7451 (0-21596)	17
Pepper, red	ESP	*Capsicum annuum L cult LR7*	Lyophilized	Y	nl=5, nw=4	791 (0-2736)	7115 (2395-20901)		245514 (0-414219)	10700 (0-17883)	17
Pepper, red	ESP	*Capsicum annuum L cult DN3*	Lyophilized	Y	nl=5, nw=4	0 (0-2313)	3210 (0-21943)		216962 (0-571435)	7460 (0-15558)	17
Pepper, red	ESP	*Capsicum annuum L cult DN5*	Lyophilized	Y	nl=5, nw=4	0 (0-5055)	7742 (6312-190305)		245219 (0-598510)	6105 (0-19776)	17
Pepper, red	ESP	*Capsicum annuum L cult RR1*	Lyophilized	Y	nl=5, nw=4	735 (0-2113)	4276 (2342-10954)		146706 (0-301257)	5834 (0-10278)	17
Pepper, red	ESP	*Capsicum annuum L cult DR6*	Lyophilized	Y	nl=5, nw=4	2558 (0-2977)	22303 (1726-23994)		469715 (0-605135)	20852 (0-23635)	17
Pepper, red	ESP	*Capsicum annuum L cult Datler*	Lyophilized	Y	nl=5, nw=4	0 (0-2041)	12221 (1608-25511)		444785 (0-543216)	15054 (0-27000)	17
Pepper, red	ESP	*Capsicum annuum L cult Mulato*	Lyophilized	Y	nl=5, nw=4	0 (0-12005)	9227 (8125-23880)		222002 (0-501188)	11301 (0-17778)	17
Pepper, red	ESP	*Capsicum annuum L var Agridulce*	Raw	Y	nl=4	443 (0-885)	4605 (793-8417)		32824 (0-65647) 3612** (0-7224)**	2578 (0-5156)	18
Pepper, red	ESP	*Capsicum annuum L var Bola*	Raw	Y	nl=4	406 (0 - 812)	3154 (1040-5268)		26161 (0-52321) 2969**	2016 (0-4031)	18

									(0-5938)**	
Pepper, red, Paprika	ESP	*Capsicum annuum L. (RR-1)*	Dried	Without	Y	nl=5, nw=4			93400 (62200-110100)	16
Pepper, yellow	BRA	*Capsicum annuum L. (F1 Magali hybrid)*	Raw	Without	Y			3080 ± 310*		15
White bryony, green	ESP	*Bryonia dioica*					17370 (1720-38330)	8930 (1010-21520)		28

* *E*-isomers; ** *Z*-isomers; LD - Limit of detection; VM - validated method; nl - number of lots; nw - number of replicates; Y – Yes; N – No; () - range

Table 3.2. Carotenoids in fruit vegetables (µg/100 g) (cont.)

Name	OC	Scientific name	Processing	Peel	SAP (Y/N)	QA	capsorubin	antheraxanthin	latoxanthin	phytofluene	phytoene	cucurbitaxanthin A	cucurbitaxanthin B	Ref
Pepper	CHL/MEX	*Capsicum annuum L., var. Ancho*	Dried		Y	nl=2	134 (105-163)	<LD	235 (53.4-417)				614 (438-790)	12
Pepper	CHL/MEX	*Capsicum annuum L., var. Guajillo*	Dried		Y	nl=2	162 (20.3-304)	239 (<LD-478)	82 (59.5-105)					12
Pepper	CHL/MEX	*Capsicum annuum L., var. Mulato*	Dried		Y	nl=2	176 (48.5-304)	<LD	163 (111-214)			100 (0-199)	407 (3.62-811)	12
Pepper, Jalapeño, green	MEX	*Capsicum annuum L.*		Without					4899 (3015-3768)					14
Pepper, red	ESP	*Capsicum annuum L. (RR-5)*	Dried	Without	N	nl=5, nw=4	83200 (57000-106500)							16

Pepper, red	ESP	*Capsicum annuum L / cultivar Mana*	Raw	Y				97200	17
Pepper, red	ESP	*Capsicum annuum L / cultivar Negral*	Raw	Y		53600			17
Pepper, red	ESP	*Capsicum annuum L cult MA1*	Lyophilized	Y	nl=5, nw=4	6666 (0-32254)	531 (0-86060)	42637 (0-91975)	17
Pepper, red	ESP	*Capsicum annuum L cult MA3*	Lyophilized	Y	nl=5, nw=4	19628 (0-28877)	26718 (394-45996)	34159 (0-69350)	17
Pepper, red	ESP	*Capsicum annuum L cult RN1*	Lyophilized	Y	nl=5, nw=4	15919 (0-40887)	29689 (465-53563)	41494 (0-97564)	17
Pepper, red	ESP	*Capsicum annuum L cult RN2*	Lyophilized	Y	nl=5, nw=4	13933 (0-35442)	26744 (499-49406)	37013 (0-89920)	17
Pepper, red	ESP	*Capsicum annuum L cult LR2*	Lyophilized	Y	nl=5, nw=4	6604 (0-23291)	17967 (566-47477)	21556 (0-60645)	17
Pepper, red	ESP	*Capsicum annuum L cult LR7*	Lyophilized	Y	nl=5, nw=4	9022 (0-19732)	30213 (379-45295)	35273 (0-59130)	17
Pepper, red	ESP	*Capsicum annuum L cult DN3*	Lyophilized	Y	nl=5, nw=4	9008 (0-18119)	19367 (491-44970)	30434 (0-80903)	17
Pepper, red	ESP	*Capsicum annuum L cult DN5*	Lyophilized	Y	nl=5, nw=4	8488 (0-23150)	20257 (657-53674)	36953 (0-86558)	17
Pepper, red	ESP	*Capsicum annuum L cult RR1*	Lyophilized	Y	nl=5, nw=4	6440 (0-12576)	15857 (358-26275)	20646 (0-38955)	17

Pepper, red	ESP	*Capsicum annuum L cult DR6*	Lyophilized		Y	nl=5, nw=4	23057 (0-29079)	54832 (164-61326)			76611 (0-79541)		17
Pepper, red	ESP	*Capsicum annuum L cult Datler*	Lyophilized		Y	nl=5, nw=4	17833 (0-28433)	48134 (230-63633)			57574 (0-82042)		17
Pepper, red	ESP	*Capsicum annuum L cult Mulato*	Lyophilized		Y	nl=5, nw=4	14501 (0-18183)	15975 (533-55002)			29276 (0-65378)		17
Pepper, red	ESP	*Capsicum annuum L var Agridulce*	Raw		Y	nl=2	7898	4408					18
Pepper, red	ESP	*Capsicum annuum L var Bola*	Raw		Y	nl=2	5344	3318					18
Pepper, red	ESP	*Capsicum annuum L*	Raw		Y	nw=4						721 ± 28	2
Pepper, red	ESP	*Capsicum annuum L*	Cooked		Y	nw=4						1034 ± 35	2
Pepper, red, Paprika	ESP	*Capsicum annuum L. (RR-2)*	Dried	Without	Y	nl=5, nw=4	41600 (19700-55400)						16
Tomato	BRA	*Lycopersicon esculentum Cultivar santa cruz*	Raw			nl=10			370 ± 4.6**				24
Tomato	BRA	*Lycopersicon esculentum*	Juice			nl=3			510 ± 1.4				24
Tomato	BRA	*Lycopersicon esculentum*	Puree			nl=18			1170 (940-1420)				24
Tomato	BRA	*Lycopersicon esculentum*	Paste			nl=12			1160 (920-1680)				24
Tomato	ESP	*Lycopersicon esculentum* M., common type	raw			nw=4				923 ± 424			2
Tomato	ESP	*Lycopersicon*	raw			nw=4				489 ±			2

		esculentum M. Canary island type						68		
Tomato	ESP	*Lycopersicon esculentum* M. Pear type	raw			nw=4		2795 ± 446		2
Tomato	ESP	*Lycopersicon esculentum*						3480-9130		29
Tomato, red	ESP	*Solanum lycopersicum* Mill, common type	Raw	without		nl=4	3015±47			8
Tomato, red	ESP	*Solanum lycopersicum Mill,* pear type	Raw	without		nl=4			1373	8
Watermelon, red	ESP	*Citrullus vulgaris, Schered*	Raw	without	N	nw=3		1150		2
Watermelon, red	ESP	*Citrullus vulgaris, Schered*	Raw	without	Y	nw=3		1122 ± 812		2

** *Z*-isomers; LD - Limit of detection; VM - validated method; nl - number of lots; nw - number of replicates; Y – Yes; N – No; () - range

Table 3.3. Carotenoids in fruit vegetables (µg/100 g) (cont.)

Name	OC	Scientific name	Processing	Peel	SAP (Y/N)	QA	cycloviolaxanthin	mutatoxanthin	mutatoxanthin 2	mutatoxanthin 1	cryptocapsin	crytoflavin	luteoxanthin	capsolutein	ζ-Carotene	ε-carotene	Ref
Pepper	CHL/MEX	*Capsicum annuum L., var. Ancho*	Dried		N	nl=2			11.3 (0–22.6)	12.4 (0–24.8)	9.1 (0-18.1)						12

Pepper	CHL/ MEX	*Capsicum annuum L., var. Guajillo*	Dried		N	nl= 2	56.1 (34.5–77.7)		10.5 (0–21.0)	10.2 (0-20.3)	570 (464-676)	140 (0-279)					12
Pepper	CHL/ MEX	*Capsicum annuum L., var. Mulato*	Dried		N	nl= 2	10.5 (0–21.0)	265 (0-529)	44.6 (0–89.1)		227 (45.0-408)	127 (0- 53)	176 (152 199)				12
Pepper, red	ESP	*Capsicum annuum L var Agridulce*	Raw		Y	nl= 2								8877			18
Pepper, red	ESP	*Capsicum annuum L var Bola*	Raw		Y	nl= 2								6896			18
Tomato	BRA	*Lycopersicon esculentum Cultivar santa cruz*	Raw			nl= 10									40 ± 0.2*		24
Tomato	BRA	*Lycopersicon esculentum*	Juice			nl= 10									130 ± 0.3		24
Tomato	BRA	*Lycopersicon esculentum*	Puree			nl= 18									270 (140-330)		24
Tomato	BRA	*Lycopersicon esculentum*	Paste			nl= 10									350 (250-500)		24
Tomato, red	ESP	*Solanum lycopersicum Mill, common type*	Raw	with out		nl= 4										143 ± 35	8

Tomato, red	ESP	*Solanum lycopersicum Mill, pear type*	Raw	without	nl=4	37 ± 4	8
Tomato, red	ESP	*Solanum lycopersicum Mill, pear type*	Raw	without	nl=4	161 ± 22	8

* *E*-isomers; LD - Limit of detection; VM - validated method; nl - number of lots; nw - number of replicates; Y – Yes; N – No; () - range

Table 4. Carotenoids in legumes (µg/100 g)

Name	Origin (Country)	Scientific name	Processing	SAP (Y/N)	QA	*β*-carotene	*β*-cryptoxanthin	lutein	zeaxanthin	Ref
Bean, kidney	PAN	*Phaseolus vulgaris*	Raw	Y	nw=4			430 ± 50	10 ± 10	7
Peas, split	CRI	*Pisum sativum var. Native*	Boiled	Y	nl=6, nw=3	79.7	2.99	480^		1

^ includes zeaxanthin; nl - number of lots; nw - number of replicates; Y – Yes; N – No

Table 5. Carotenoids in leafy vegetables (µg/100 g)

Name	Origin (Country)	Scientific name	Processing	SAP (Y/N)	QA	*α*-carotene	*β*-carotene	*β*-cryptoxanthin	lycopene	lutein	zeaxanthin	Ref
Beetroot leaves	PRT	*Beta vulgaris L. var. vulgaris*	Raw	N	VM	<LD	2500	<LD	<LD	4400	<LD	9
Chicory	BRA	*Cichorium intybus*	Raw	N	nl=6, nw=2		3530 ± 500			5370 ± 830		13
Chicory	BRA	*Chicorium intybus*	Raw	N	nl=5, nw=10		3600			5700		3

Endive	PAN	*Cichorium endivia*	Raw	Y	nw=4					3420 ± 400	50 ±10	7
Endive	BRA	*Chicorium endivia*	Raw		nl=29, nw=2		2490 (1340-4350)			3710 (2060-6150)		30
Endive	BRA	*Chicorium endivia*	Stir-fried	Y	nl=5		1240 ± 370			2340 ± 500		5
Endive	BRA	*Chicorium endivia*	Raw	N	nl=10, nw=10		2490 (3100-4400)			3710 (4300-6200)		3
Endive	BRA	*Chicorium endivia*	Stir-fried	Y	nl=5		1240 ± 370			2340 ± 500		5
Green amaranth	BRA	*Amaranthus viridis*		N	nl=5, nw=10		3200 ± 1400			3400 ± 1400		3
Leef Beet greens	PRT	*Beta vulgaris L. ssp. vulgaris convar. cicla (L.)*	Raw	N	VM	<LD	2900	<LD	<LD	3600	130	9
Lettuce	PAN	*Lactuca sativa*	Raw	Y	nw=4					200 ± 10	10 ± 10	7
Lettuce	ESP	*Lactuca sativa L. (Romaine-Carrascoy)*	Raw	N	nw=4		2640 ± 300			1170 ± 90		31
Lettuce	ESP	*Lactuca sativa L. (Romaine-España)*	Raw	N	nw=4		2460 ± 500			1000 ± 210		31
Lettuce	ESP	*Lactuca sativa L. (Romaine-Aitana)*	Raw	N	nw=4		3490 ± 230			1390 ± 120		31
Lettuce	ESP	*Lactuca sativa L. (Romaine-Collado)*	Raw	N	nw=4		3200 ± 90			1160 ± 20		31
Lettuce	ESP	*Lactuca sativa L. (Romaine-Alhama)*	Raw	N	nw=4		3390 ± 280			1340± 100		31
Lettuce	ESP	*Lactuca sativa L. (Romaine-Isasa)*	Raw	N	nw=4		2010 ± 130			770 ± 50		31
Lettuce	ESP	*Lactuca sativa L. (Romaine- AR-29213)*	Raw	N	nw=4		3300± 220			1410 ± 110		31

Lettuce	ESP	*Lactuca sativa L. (Little Gem - Ricote)*	Raw	N	nw=4	2050 ± 100		780 ± 30	31
Lettuce	ESP	*Lactuca sativa L. (Little Gem - Petra)*	Raw	N	nw=4	1950 ± 100		780 ± 70	31
Lettuce	ESP	*Lactuca sativa L. (Little Gem - Etna)*	Raw	N	nw=4	1880 ± 220		840 ± 70	31
Lettuce	ESP	*Lactuca sativa L. (Little Gem - Urbión)*	Raw	N	nw=4	2060 ± 50		840 ± 40	31
Lettuce	ESP	*Lactuca sativa L. (Little Gem - Sandra)*	Raw	N	nw=4	2070 ± 410		870 ± 130	31
Lettuce	ESP	*Lactuca sativa L. (Little Gem - Maite)*	Raw	N	nw=4	2270 ± 290		970 ± 130	31
Lettuce	ESP	*Lactuca sativa L. (Little Gem - Ferro)*	Raw	N	nw=4	2030 ± 340		780 ± 110	31
Lettuce	ESP	*Lactuca sativa L. (Mini Romaine - Marta)*	Raw	N	nw=4	4180 ± 590		1490 ± 200	31
Lettuce	ESP	*Lactuca sativa L. (Mini Romaine - AR-29232)*	Raw	N	nw=4	3330 ± 140		1270 ± 40	31
Lettuce		*Lactuca sativa L.*			nl=4	172 ± 8		340 ± 17	8
Lettuce, Boston	BRA	*Lactuca sativa var. Boston*	Raw	N	nl=4, nw=2	1850 (870-2960)		2058 (1000-3090)	30
Lettuce, Boston	BRA	*Lactuca sativa*	Raw	N	nl=6, nw=2	1490 ± 460		1350 ± 430	13
Lettuce, butterhead	CRI	*Lactuca sativa L. var. capitata cv. Karla*		Y	nl=3, nw=3	199 160*	25.4**	1180^	1
Lettuce, curly	BRA	*Lactuca sativa*	Raw	N	nl=6, nw=2	1550 ± 420		1430 ± 240	13

Lettuce, curly	BRA	*Lactuca sativa*	Raw	N	nl=10, nw=10		1650 (1600-1700)			1450 (1400-1500)		3
Lettuce, Freelice	BRA	*Lactuca sativa*	Raw	N	nl=5, nw=10		990			1000		3
Lettuce, French	BRA	*Lactuca sativa*	Raw	N	nl=5, nw=10		2500			2300		3
Lettuce, iceberg	ESP	*Lactuca sativa L. iceberg*			nl=4		48 ± 2			140 ± 3		8
Lettuce, Iceberg	CRI	*Lactuca sativa L. varcapitata cv. Cool Breeze*	Raw	Y	nl=3, nw=3		192 153*		24.1**	2520^		1
Lettuce, Romaine	PAN	*Lactuca sativa (longifolia)*	Raw	Y	nw=4					2110 ± 140	70 ± 10	7
Lettuce, Smooth	BRA	*Lactuca sativa*	Raw	N	nl=10, nw=10		1900 (1500-2300)			1750 (1400-2100)		3
Mentruz	BRA	*Lepidium pseudodidymum*	Raw	N	nl=5, nw=10	470 ± 180	11400 ± 2200			11900 ± 2100		17
Mustard Greens	CRI	*Brassica juncea var. Native*	Boiled	Y	nl=5, nw=3	4.23	2130 1700*	35	22 20.8**	3330^		1
Purslane	PRT	*Portulaca oleracea L. ssp. sativa (Haw.) Schubl. & Mart.*	Raw	N	VM	9	3500	<LD	<LD	5400	190	9
Purslane	BRA	*Portulaca oleracea*	Raw	N	nl=5, nw=10		6500 ± 1300			8800 ± 1800		3
Rucula	ESP	*Eruca sativa*	Raw	N	nw=3	<LD	3575	<LD	<LD	8061	<LD	21
Rucula	BRA	*Eruca sativa*	Raw	N	nl=6, nw=2		2840 ± 150			5000 ± 440		13
Rucula	BRA	*Eruca sativa*	Raw	N	nl=10, nw=10		3050 (2800-3300)			5100 (5000-5200)		3
Sow thistle	BRA	*Sonchus oleraceus*	Raw	N	nl=5, nw=10		9700 ± 4000			11100 ± 4800		3
Spinach	PAN	*Spinacea juncea*	Raw	Y	nw=4					4370 ± 380	70 ± 10	7
Spinach	CRI	*Spinacia oleraceae var. Native*	Boiled	Y	nl=3, nw=3		807 494*			4100^		1

Spinach	ESP	*Spinacia oleraceae L.*	Raw		n=4		3254 ± 330*			4229 ±1310	377 ± 103	8
Spinach	ESP	*Spinacia oleraceae L.*	Cooked				4626 ± 346*			6422 ± 1190	564 ± 75	8
Spinach, New Zealand	BRA	*Tetragonia tetragonioides*	Raw	N	nl=2, nw=2		3825 (2230-5490)			4810 (3640-7210)		30
Spinach, New Zealand	BRA	*Tetragonia expansa*	Raw	N	nl=10, nw=10		5300 (5100-5500)			7000 (6800-7200)		3
Taioba	BRA	*Xanthosoma sagittifolium*	Raw	N	nl=5, nw=10		5500 ± 500			7400 ± 600		3
Turnip greens	PRT	*Brassica rapa L. var. rapa*	Raw	N	VM	<LD	4400	<LD	<LD	5600	<LD	9
Watercress	BRA	*Nasturtium officinale*	Raw	N	nl=6, nw=2		2720 ± 450			5610 ± 730		13
Watercress	BRA	*Nasturtium officinalis*	Raw	N	nl=10, nw=10		3200 (2700-3700)			6550 (5600-7500)		3
Watercress	ESP	*Valerianella locusta*	Raw	N	nw=3	<LD	2655	<LD	<LD	4357	<LD	21
Watercress	PAN	*Nasturitum officinale*	Raw	Y	nw=4					4280 ± 380	40 ± 10	7

* *E*-isomers; ** *Z*-isomers; ^ includes zeaxanthin; LD - Limit of detection; VM - validated method; nl - number of lots; nw - number of replicates; Y – Yes; N – No; () - range

Table 5.1. Carotenoids in leafy vegetables (μg/100 g) (cont.)

Name	Origin (Country)	Scientific name	Processing	SAP (Y/N)	QA	neoxanthin	violaxanthin	auroxanthin	crytoflavin	lactucaxanthin	Ref
Chicory	BRA	*Cichorium intybus*	Raw	N	nl=6, nw=2	2050 ± 480	3170 ± 810				13
Chicory	BRA	*Chicorium intybus*	Raw	N	nl=5, nw=10	1500	2100				3
Endive	PAN	*Cichorium endivia*	Raw	Y	nw=4			371	106		7
Endive	BRA	*Chicorium*	Raw		nl=29, nw=2	1250	1600				30

		endivia				(490-2200)	(970-2880)	
Endive	BRA	*Chicorium endivia*	Stir-fried	Y	nl=5	700 ± 200	680 ± 150	5
Endive	BRA	*Chicorium endivia*	Raw	N	nl=10, nw=10	1900 (1600-2200)	2600 (2300-2900)	3
Endive	BRA	*Chicorium endivia*	Stir-fried	Y	nl=5	700 ± 200	680 ± 150	5
Lettuce	ESP	*Lactuca sativa L. (Romaine-Carrascoy)*	Raw	N	nw=4	340 ± 30	590 ± 30	31
Lettuce	ESP	*Lactuca sativa L. (Romaine-España)*	Raw	N	nw=4	320± 60	550 ± 100	31
Lettuce	ESP	*Lactuca sativa L. (Romaine-Aitana)*	Raw	N	nw=4	460 ± 40	750 ± 50	31
Lettuce	ESP	*Lactuca sativa L. (Romaine-Collado)*	Raw	N	nw=4	350 ± 10	530 ± 30	31
Lettuce	ESP	*Lactuca sativa L. (Romaine-Alhama)*	Raw	N	nw=4	410 ± 30	620 ± 40	31
Lettuce	ESP	*Lactuca sativa L. (Romaine-Isasa)*	Raw	N	nw=4	230 ± 30	500 ± 120	31
Lettuce	ESP	*Lactuca sativa L. (Romaine- AR-29213)*	Raw	N	nw=4	450 ± 60	690 ± 70	31
Lettuce	ESP	*Lactuca sativa L. (Little Gem - Ricote)*	Raw	N	nw=4	260 ± 20	450 ± 30	31
Lettuce	ESP	*Lactuca sativa L. (Little Gem - Petra)*	Raw	N	nw=4	250 ± 20	460 ± 10	31
Lettuce	ESP	*Lactuca sativa L. (Little Gem - Etna)*	Raw	N	nw=4	260 ± 20	430 ± 30	31

Lettuce	ESP	*Lactuca sativa L. (Little Gem - Urbión)*	Raw	N	nw=4	270 ± 10	480 ± 30		31
Lettuce	ESP	*Lactuca sativa L. (Little Gem - Sandra)*	Raw	N	nw=4	270± 40	490 ± 60		31
Lettuce	ESP	*Lactuca sativa L. (Little Gem - Maite)*	Raw	N	nw=4	310 ± 30	530 ± 70		31
Lettuce	ESP	*Lactuca sativa L. (Little Gem - Ferro)*	Raw	N	nw=4	250 ± 40	420 ± 50		31
Lettuce	ESP	*Lactuca sativa L. (Mini Romaine - Marta)*	Raw	N	nw=4	500 ± 70	750 ± 60		31
Lettuce	ESP	*Lactuca sativa L. (Mini Romaine - AR-29232)*	Raw	N	nw=4	390 ± 10	620 ± 30		31
Lettuce, Boston	BRA	*Lactuca sativa var. Boston*	Raw	N	nl=4, nw=2	1050 (660-1920)	2655 (1250-3730)		30
Lettuce, Boston	BRA	*Lactuca sativa*	Raw	N	nl=6, nw=2	750 ± 200	1800 ± 490	750 ± 340	13
Lettuce, curly	BRA	*Lactuca sativa*	Raw	N	nl=6, nw=2	760 ± 160	1870 ± 290	670 ± 180	13
Lettuce, curly	BRA	*Lactuca sativa*	Raw	N	nl=10, nw=10	700 (640-760)	1650 (1400-1900)		3
Lettuce, Freelice	BRA	*Lactuca sativa*	Raw	N	nl=5, nw=10	540	810		3
Lettuce, French	BRA	*Lactuca sativa*	Raw	N	nl=5, nw=10	1100	2000		3
Lettuce, Smooth	BRA	*Lactuca sativa*	Raw	N	nl=10, nw=10	8700 (7500-9900)	1850 (1800-1900)		3
Mentruz	BRA	*Lepidium pseudodidymum*	Raw	N	nl=5, nw=10	2600 ± 600	6200 ± 1000		17
Purslane	BRA	*Portulaca oleracea*	Raw	N	nl=5, nw=10	2200 ± 300	3600 ± 500		3
Rucula	BRA	*Eruca sativa*	Raw	N	nl=6, nw=2	1810 ± 550	2970 ± 730		13

Rucula	BRA	*Eruca sativa*	Raw	N	nl=5, nw=10	1800	4000				3
Rucula	BRA	*Eruca sativa*	Raw	N	nl=5, nw=10	1200	2100				3
Sow thistle	BRA	*Sonchus oleraceus*	Raw	N	nl=5, nw=10	3100 ± 1600	5800 ± 2300				3
Spinach, New Zealand	BRA	*Tetragonia tetragonioides*	Raw	N	nl=24, nw=2	1480 (1770-2220)	2005 (1580-3930)				30
Spinach, New Zealand	BRA	*Tetragonia expansa*	Raw	N	nl=10, nw=10	2200	3500 (3100-3900)				3
Taioba	BRA	*Xanthosoma sagittifolium*	Raw	N	nl=5, nw=10	1800 ± 200	3700 ± 500				3
Watercress	BRA	*Nasturtium officinale*	Raw	N	nl=6, nw=2	1770 ± 170	2610 ± 630				13
Watercress	BRA	*Nasturtium officinalis*	Raw	N	nl=10, nw=10	1750 (1700–1800)	2600				3

LD - Limit of detection; VM - validated method; nl - number of lots; nw - number of replicates; Y – Yes; N – No; () - range

Table 6. Carotenoids in bulb, stalk and stem vegetables (µg/100 g)

Name	Origin (Country)	Scientific name	Process	SAP (Y/N)	QA	*β*-carotene	lutein	zeaxanthin	neoxanthin	violaxanthin	Ref
Artichoke	ESP	*Cynara scolymus L.*	Raw		nl=4	47 ± 5	163 ± 15				8
Artichoke	ESP	*Cynara scolymus L.*	Cooked		nl=4	59 ± 1	275 ± 23				8
Asparagus	ESP	*Asparragus officinallis L.*	Raw		nl=4	320 ± 50	609 ± 20				8
Asparagus	ESP	*Asparragus officinallis L.*	Cooked		nl=4	387 ± 49	738 ± 25				8

Asparagus, Wild young shoots	ESP	*Asparagus acutifolius*			nw=8	339 (159-421)	544 (410-850)		517 (36-979)	387 (261-574	28
Asparagus, Wild young shoots	ESP	*Tamus communis L.*			nw=8	458 (320-599)	1054 (704-1735)		1055 (766-1897)	510 (380-1093)	28
Asparagus, Wild young shoots	ESP	*Bryonia dioica Jacq.*			nw=8	669 (149-1953)	1913 (683-3698)		1737 (172-893)	893 (28-2152)	28
Asparagus, Wild young shoots	ESP	*Humulus lupulus L.*			nw=8	376 (156-1263)	549 (188-1720)		723 (132-1570)	208 (41-673)	28
Leek	ESP	*Allium tricoccum L.*	Raw	N	nw=4	75 (51-99)	124 (76-171)	12 (5-19)			2
Onion	ESP	*Allium cepa L.*	Raw		nl=4	1 ± 0.4	2 ± 0.5	<LD			8
Onion	ESP	*Allium cepa L.*	Cooked		nl=4	3 ± 0.3	5 ± 0.5	<LD			8
Peach palm, orange	PAN	*Bactris gasipaes*	Raw	Y	nw=4		90 ± 20	<LD	3100 ± 1600	5800 ± 2300	7
Peach palm, red	PAN	*Bactris gasipaes*	Raw	Y	nw=4		120 ± 20	<LD	1800 ± 200	3700 ± 500	7

LD - Limit of detection; VM - validated method; nl - number of lots; nw - number of replicates; Y – Yes; N – No; () - range

Table 7. Carotenoids in non-starchy root vegetables (µg/100 g)

Name	Origin (Country)	Scientific name	Process	SAP (Y/N)	QA	*α*-carotene	*β*-carotene	*β*-cryptoxanthin	lycopene	lutein	zeaxanthin	phytoene	Ref
Beet	CRI	*Beta vulgaris cv. Boro*	Boiled	Y	nl=5, nw=3					8.84^			1
Beet	PAN	*Beta vulgaris*	Raw	Y	nw=4					5310 ± 610	70 ± 10		7
Beet	ESP	*Beta vulgaris L.*	Raw		nl=4		1095 ± 61			1503 ± 101			8
Beet	ESP	*Beta vulgaris L.*	Cooked		nl=4		1360 ± 34			1960 ± 85			8
Carrot	PAN	*Daucus carota*	Raw	Y	nw=4					360 ± 50	ND		7
Carrot	BRA	*Daucus carota cv*	Raw	N	nl=6, nw=2	3500 ± 500	6150 ± 900			510 ± 100			13

		Nantes									
Carrot	CRI	*Daucus carota cv. Bangor*	Boiled	Y	nl=6, nw=3	2390	4500 4313*	86.4 85.4**	2970^		1
Carrot	CRI	*Daucus carota cv. Bangor*	Raw	Y	nl=3, nw=3	3860	7100 6920*	149 146**	157^		1
Carrot	ESP	*Daucus carota L*	Raw		nl=4	2895 ± 276	6628 ± 45*		288 ± 33		8
Carrot	ESP	*Daucus carota L*	Cooked		nl=4	3245 ± 128	8162 ± 364*		273 ± 35		8
Carrot	ESP	*Daucus carota L*	Raw	N	nw=4					1769 ± 86	2
Carrot	ESP	*Daucus carota L*	Cooked	N	nw=4					1197 ± 414	2
Carrot	ESP	*Daucus carota L*			nw=4					7460-12440	29
Carrot	MEX	*Daucus carota L.*	Raw			830	3078				14
Carrot	MEX	*Daucus carota L.*				13060^{dw} (6350-19769)^{dw}	52268^{dw} (34659- 69876)^{dw}				14

^{dw} - dry weight basis; * *E*-isomers; ** *Z*-isomers; ^ includes zeaxanthin; LD - Limit of detection; VM - validated method; nl - number of lots; nw - number of replicates; Y – Yes; N – No; () - range

Table 8. Carotenoids in vegetables with pods (µg/100 g)

Name	Origin (Country)	Scientific name	Processing	SAP (Y/N)	QA	*α*-carotene	*β*-carotene	*β*-cryptoxanthin	lycopene	lutein	neoxanthin	violaxanthin	Ref
Green bean	BRA	*Phaseolus vulgaris*	Boiled	Y	nl=55		163 (130-200)			243 (220-290)	<LD	<LD	5
Green bean	BRA	*Phaseolus vulgaris*	Stir-fried	Y	nl=15, nw=2	<LD	178 (170-180) 2667* (2500-2900)*			273 (250-290)	<LD	<LD	5
Green bean	ESP	*Phaseolus vulgaris, Savi*	Raw		nw=4	35 ± 2	166 ± 10			365 ± 7			8

Green bean	ESP	*Phaseolus vulgaris, Savi*	Cooked		nw=4	79 ± 2	238 ± 15			487 ± 5		8
String bean	CRI	*Phaseolus vulgaris cv. Provider*	Boiled	Y	nl=6, nw=2	79.6	476 371*	19.4	18.2**	1160^		1

* *E*-isomers; ** *Z*-isomers; ^ includes zeaxanthin; LD - Limit of detection; VM - validated method; nl - number of lots; nw - number of replicates; Y – Yes; N – No; () - range

Table 9. Carotenoids in berry fruits (μg/100 g)

Name	**Origin (Country)**	**Scientific name**	**Process**	**SAP (Y/N)**	**QA**	***α*-carotene**	***β*-carotene**	***β*-cryptoxanthin**	**lycopene**	**lutein**	**zeaxanthin**	**Ref**
American gooseberry	BRA	*Pereskia aculeata* Mill	Raw	Y	nw=3	2270 ± 60	3430±60* 280±10**	220 ± 20		650 ± 40	270 ± 20***	32
Goji berries	ESP	*Lycium barbarum*	Raw	Y	nw=3	<LD	483	1100	<LD	331	3260	21
Grape	ESP	*Vitis vinifera L.*	Raw	N	nw=4	<LD	17 ± 2	<LD	<LD	13	<LD	2
Sarsaparilla	ESP	*Smilax aspera* L.		N	nl=4		6576 ± 2.57		24244 ± 31.69*		435 ± 0.78*	33
Sarsaparilla	ESP	*Smilax aspera* L.		N	nl=4			742 ± 0.44*			398 ± 0.37* (monomyristate)	33
Sarsaparilla	ESP	*Smilax aspera* L.		N	nl=4			734 ± 0.67* (caprate)				33
Sarsaparilla	ESP	*Smilax aspera* L.		N	nl=4			888 ± 0.74* (laurate)				33
Sarsaparilla	ESP	*Smilax aspera* L.		N	nl=4			886 ± 0.83* (myristate)				33
Sarsaparilla	ESP	*Smilax aspera* L.		N	nl=4			97 ± 0.02* (oleate)				33

Sarsaparilla	ESP	*Smilax aspera* L.		N	nl=4			526 ± 0.11* (palmitate)				33
Sarsaparilla	ESP	*Smilax aspera* L.		N	nl=4			341 ± 0.32* (stearate)				33
Strawberry	BRA	*Fargaria vesca* L., var. Oso Grande	Raw		VM, nl=2, nw=6		53.55 (53.02- 54.08)		<LD			34
Strawberry	ESP	*Fragaria elatior, Ehrh.*	Raw	N	nw=3	<LD	5.5	<LD		14.5	0.9	2,27
Strawberry	ESP	*Fragaria elatior, Ehrh.*	Raw	Y	nw=3	<LD	3.7 ± 1	<LD		13.6 ± 7	0.6	2,27
Wild rose	ESP	*Rosa mosqueta* (*Rosa rubiginosa, Rosa eglanteria*)		Y	nl=10		49760 ± 32.1	18350 ± 12.6	39190 ± 28.3		26660 ± 15.3	6

* *E*-isomers; ** *Z*-isomers; ***includes α-cryptoxanthin; ^ includes zeaxanthin; LD - Limit of detection; VM - validated method; nl - number of lots; nw - number of replicates; Y – Yes; N – No; () - range

Table 9.1. Carotenoids in berry fruits (μg/100 g) (cont.)

Name	**Origin (Country)**	**Scientific name**	**Process**	**SAP (Y/N)**	**QA**	**neoxanthin**	**violaxanthin**	**neurosporene**	**antheraxanthin**	**lycophyll**	**Ref**
Sarsaparilla	ESP	*Smilax aspera* L.		N	nl=4	1370 ± 2.11			58 ± 0.21	1370 ± 2.11	33
Wild rose	ESP	*Rosa mosqueta* (*Rosa rubiginosa, Rosa eglanteria*)		Y	nl=10		70370 ± 40.5	28920 ± 21.1			6

^ includes zeaxanthin; LD - Limit of detection; VM - validated method; nl - number of lots; nw - number of replicates; Y – Yes; N – No; () - range

Table 10. Carotenoids in citrus fruits (µg/100 g)											
Name	**Origin (Country)**	**Scientific name**	**SAP (Y/N)**	**QA**	***α*-carotene**	***β*-carotene**	***β*-cryptoxanthin**	**lycopene**	**lutein**	**zeaxanthin**	**Ref**
Grapefruit, red	PAN	*Citrus grandis*	Y	nw=4					20 ± 10	20 ± 10	35
Lemon	ESP	*Citrus limonis, Osbeck*	Y	nw=3	<LD	0.4	14.4 ± 2	<LD	2.5 ± 0.3	1.2 ± 0.3	2,27
Lemon, sweet	CRI	*Citrus limetta var. native*	Y	nl=4, nw=3	28.1	261	428				1
Mandarin	PAN	*Citrus reticulata*	Y	nw=4					200 ± 30	210 ± 20	35
Mandarin	PAN	*Citrus reticulata*	Y	nw=4	<LD	213 ± 102	843 ± 216	<LD	<LD	<LD	2
Mandarin, juice	PAN	*Citrus reticulata*	Y	nw=4					160 ± 20	170 ± 30	35
Orange	PAN	*Citrus sinensis*	Y	nw=4					30 ± 10	30 ± 10	35
Orange	ESP	*Citrus sinensis L. var Navel late*	Y		5 ± 0.0	9 ± 0.0	85 ± 0.0 1		36 ± 0.00* 14 ± 0.00**	47 ± 0.00*	36
Orange	ESP	*Citrus sinensis L.*	N	nw=3		42.5	48.9	<LD	11.2	12.4	2,27
Orange	ESP	*Citrus sinensis L.*	Y	nw=3	12.8 ± 5	48.4 ± 12	448.3 ± 27	<LD	68 ± 20	65.6 ± 19	2,27
Orange	PRT	*Citrus sinensis L. var. Navel Lane Late*	Y	VM, nl=4, nw=2	13* (11-27)*	31* (17-49)*	180* (110-230)*	<LD	37 (34-72)	86 (66-190)	9

Orange	CRI	*Citrus sinensis cv. Valencia*	Y	nl=3, nw=3	23.1	41.8 29.2*	47.3		312^		1
Orange, grafted	PAN	*Citrus sinensis*	Y	nw=4					70 ± 20	110 ± 20	7
Orange, grafted, juice	PAN	*Citrus sinensis*	Y	nw=4					50 ± 10	60 ± 10	7
Orange, juice	ESP	*Citrus sinensis L. var Navel late*	Y	nl=2	4.5 (4-5)	8.5 (8-9)	78 (71-85)		33* (30-35)* 13** (11-14)**	44* (40-47)*	36
Orange, juice	ESP	*Citrus sinensis L. var Valencia late*	Y	nl=18	29 (27-32)	78 (72-88)	168 (166-209)	26** (26-41)**	126* (117-139)*	219* (193-252)* 106** (99-140)**	37
Orange, juice	PAN	*Citrus simensis*	Y	nw=4					10 ± 10	10 ± 10	7
Orange, juice	ESP		Y	nl=17	11 ± 5	21 ± 7	69 ± 27				38
Orange, juice	CRI	*Citrus sinensis cv. Valencia*	Y	nl=6, nw=3	3.78	35.4 27.7*	5.87		26.6^		1
Orange, juice	ESP	*Citrus sinensis*		nl=25			0.041 ± 0.022	0.003 ± 0.004	0.023 ± 0.009	0.035 ± 0.011	39
Orange, juice	ESP	*Citrus sinensis L.*					0.0-100				40
Orange, juice	BRA	*Citrus sinensis cv. Valencia*					100-800				41
Tangerine	CRI	*Citrus nobilis var. native*	Y	nl=6, nw=3	28.1	261	428		166^		1
Tangerine, juice	ESP	*Citrus reticulata L.*					800				40

* *E*-isomers; ** *Z*-isomers; LD - Limit of detection; VM - validated method; nl - number of lots; nw - number of replicates; Y – Yes; N – No; () - range

Table 10.1. Carotenoids in citrus fruits (µg/100 g) (cont.)

Name	Origin (Country)	Scientific name	SAP (Y/N)	QA	ζ-carotene	auroxanthin	luteoxanthin	zeinoxanthin	antheraxanthin	neochrome	violaxanthin	mutatoxanthin	phytoene	Ref
Orange	ESP	*Citrus sinensis* L. var Navel late	Y		46 ± 0.01	177 ± 0.07				46 ± 0.01 13 ± 0.00**		76 ± 0.01**		36
Orange	ESP	*Citrus sinensis* L.	N	nw=4									1065 ± 74	2
Orange, juice	ESP	*Citrus sinensis* L. var Navel late	Y	nl=2	42 (37-46)	152 (139-164)				41 (3 -44) 12** (10-13)**		67** (61-72)**		36
Orange, juice	ESP	*Citrus sinensis* L. var Valencia late	Y	nl=18			58 (52-60)	61 (56-70)	323 (278-373)		336 (283-412)	109** (106-115)**		37

** *Z*-isomers; LD - Limit of detection; VM - validated method; nl - number of lots; nw - number of replicates; Y – Yes; N – No; () - range

Table 11. Carotenoids in pome fruits (µg/100 g)

Name	Origin (Country)	Scientific name	SAP (Y/N)	Q A	*α*-carotene	*β*-carotene	*β*-cryptoxanthin	lycopene	lutein	zeaxanthin	Ref
Apple	PRT	*Malus domestica Borkh var. bravo esmolfe*	Y	VM, nl=2, nw=2	1.3	10	0.9	<LD	17	1.9	9
Apple	PRT	*Malus domestica Borkh var. golden delicious*	Y	VM, nl=7, nw=2	<LD	49 (34-63)	<LD	<LD	2.4 (1.6–3.2)	1.8 (<LD–1.8)	9

Apple	PRT	*Malus domestica Borkh var. jonagold*	Y	VM, nl=5	<LD	26	<LD	<LD	3.5	<LD	9
Apple	PRT	*Malus domestica Borkh var. reineta parda*	Y	VM, nl=5	<LD	17	4	<LD	10	2	9
Apple	PRT	*Malus domestica Borkh var. royal gala*	Y	VM, nl=5, nw=2	<LD	11	<LD	<LD	2.2	3	9
Apple	PRT	*Malus domestica Borkh var. starking*	Y	VM, nl=9, nw=2	<LD	36 (13-48)	<LD	<LD	10 (9.7-16)	1.8 (<LD–2.2)	9
Apple	CRI	*Malus domestica cv. Delicious*	Y	VM, nl=5, nw=2		27.6 23.5*	12.1		24.6^		1
Apple	ESP	*Pyrus malus L.*	N	nw=3	<LD	18.7	<LD	<LD	1.5	<LD	2,27
Apple	ESP	*Pyrus malus L.*	Y	nw=3	<LD	20.5 ± 4	7.9 ± 4	<LD	6.2 ± 0.6	0.6	2,27
Japanese medlar	ESP	*Eriobotrya japonica*	Y	nw=4	<LD	977 ± 132	663 ± 109	<LD	<LD	<LD	2
Loquat	BRA	*Eriobotrya japonica Lindl. (Centenária)*	Y	nw=2		858.5* 28.1**	278.4* 5.8**		3.9*		42
Loquat	BRA	*Eriobotrya japonica Lindl. (Mizauto)*	Y	nw=2		980.9* 64.1**	480.2* 15.1**		12.5*		42

Loquat	BRA	*Eriobotrya japonica Lindl. (Mizuho)*	Y	nw=2		1090.7* 66.9**	557.6* 20.1**		13.5*		42
Loquat	BRA	*Eriobotrya japonica Lindl. (Mizumo)*	Y	nw=2		1441.5* 51.9**	715.2* 16.6**		7.9*		42
Loquat	BRA	*Eriobotrya japonica Lindl. (Néctar de Cristal)*	Y	nw=2		38.1* 7.3**	54.8* 4**		6.4*		42
Loquat	CRI	*Eriobotrya japonica var. Native*	Y	nl=3, nw=3		73.3 55.9*	24.3		106^		1
Pear	PRT	*Pyrus communis L., var. rocha*	Y	VM, nl=3, nw=2	<LD	<LD	0.9-2.5	<LD	4.3-8.8	<LD	9
Pear	CRI	*Pyrus communis cv. Green Anjou*	Y	VM, nl=3, nw=3		27.6	12.2		24.6^		1
Pear	ESP	*Pyrus communis L.*	N	nw=3	<LD	0.7	0.4	<LD	2.4	<LD	2,27
Pear	ESP	*Pyrus communis L.*	Y	nw=3	<LD	2.5 ± 0.5	2.9 ± 0.3	<LD	11.3 ± 2	<LD	2,27
Quince	PAN	*Gustavia superba*	Y	nw=4					670 ± 50	3760 ± 400	7

* *E*-isomers; ** *Z*-isomers; LD - Limit of detection; VM - validated method; nl - number of lots; nw - number of replicates; Y – Yes; N – No; () - range

Table 11.1. Carotenoids in pome fruits (μg/100 g) (cont.)

Name	Origin (Country)	Scientific name	SAP (Y/N)	Q A	phytoene	violaxanthin	neoxanthin	neochrome	Ref

Apple	ESP	*Pyrus malus L.*	N	nw= 3	<LD				2,27
Apple	ESP	*Pyrus malus L.*	Y	nw= 3	<LD				2,27
Loquat	BRA	*Eriobotrya japonica Lindl. (Centenária)*	Y	nw= 2	25.3 1.7* 12.5**	9.3*, *** 2.4**	<LD	0.3*	42
Loquat	BRA	*Eriobotrya japonica Lindl. (Mizauto)*	Y	nw= 2	22 1.9* 8.5**	12.9*,**** 5.4**	<LD	1.5*	42
Loquat	BRA	*Eriobotrya japonica Lindl. (Mizuho)*	Y	nw= 2	22.1 3.3* 10.1**	22.7*,**** 7.1**	<LD	1.9*	42
Loquat	BRA	*Eriobotrya japonica Lindl. (Mizumo)*	Y	nw= 2	34 3.4* 19.3**	28.2*,**** 12.8**	<LD	6.4*	42
Loquat	BRA	*Eriobotrya japonica Lindl. (Néctar de Cristal)*	Y	nw= 2	<LD	4.4*,**** 2.3**	0.2*	1.2*	42
Pear	ESP	*Pyrus communis L*	N	nw= 3	12.1				2,27
Pear	ESP	*Pyrus communis L*	Y	nw= 3	28.5 ± 8				2,27

* E-isomers; ** Z-isomers; ***includes α-cryptoxanthin; ****includes 9-cis-neoxanthin; LD - Limit of detection; VM - validated method; nl - number of lots; nw - number of replicates; Y – Yes; N – No; () - range

Table 12. Carotenoids in stone fruits (µg/100 g)

Name	Origin (Country)	Scientific name	SAP (Y/N)	QA	*α*-carotene	*β*-carotene	*β*-cryptoxanthin	lycopene	lutein	zeaxanthin	violaxanthin	phytoene	Ref
Apricot	PAN	*Prunus armeniaca*	Y	nw=4					60 ± 10	30 ± 10			2
Apricot	ESP	*Prunus armeniaca L.*	N	nw=3	<LD	132	11.1	<LD	<LD	<LD		3151 ± 613	2,27
Apricot	ESP	*Prunus armeniaca L.*	Y	nw=3	<LD	140 ± 25	27.5 ± 11	<LD	<LD	<LD			2,27
Cherry	PRT	*Prunus avium L., var. de saco*	Y	VM, nl=3, nw=2	29 ± 6.96* (23-37)	82 ± 4.59* (78-87)	21 ± 2.73* (18-23)	<LD	130 ± 2.73 (100-160)	27 ± 0.43 (16-33)			9
Cherry	ESP	*Prunus avium L.*	N	nw=3	<LD	14.3	2.7	12.8	2.6	<LD			2,27
Cherry	ESP	*Prunus avium L.*	Y	nw=3	1.6 ± 0.4	13.2 ± 5	4.8 ± 1	10.2 ± 0	44.3 ± 12	4.1 ± 0.4			2,27
Nectarin	PAN	*Prunus persica*	Y	nw=4					30 ± 10	20 ± 10			7
Peach	PRT	*Prunus persica L. var. M Carnival*	Y	VM	8.2*	170*	210*	<LD	75	26			9
Peach	BRA	*Prunus persica (Diamante)*	Y	nl=5, nw=2		40 ± 6*	640 ± 110 590 ± 110 *				12		43
Peach	BRA	*Prunus persica (Coral)*	Y	nl=5, nw=2		3 ± 4*	8 ± 0 8 ± 0*						43
Peach	BRA	*Prunus persica (Xiripá)*	Y	nl=5, nw=2		6 ± 1*	7 ± 1 6 ± 2 *						43
Peach	ESP	*Prunus persica Sieb. (hybrid)*	N	nw=3	3.2	69.2	15.9	<LD	1.5	10.1		524 ± 125	2,27

Peach	ESP	*Prunus persica Sieb. (hybrid)*	Y	nw=3	3.5 ± 2	64 ± 0.2	73.5 ± 13	<LD	15.7 ± 4	31.5 ± 9	2,27
Peach, canned	CRI	*Prunus persica*	Y	VM, nw=3	8.64	858 646*	614	47.3 13.6*	535^		1
Plum, yellow	ESP	*Prunus domestica*	Y	nw=4	<LD	117 ± 18	<LD	<LD	83 ± 8	<LD	2
Plum, european	PAN	*Prunus domestica*	Y	nw=4					90 ± 20	10 ± 10	7

* *E*-isomers; ** *Z*-isomers; LD - Limit of detection; VM - validated method; nl - number of lots; nw - number of replicates; Y – Yes; N – No; () - range

Table 13. Carotenoids in tropical and sub-tropical fruits (µg/100 g)

Name	Origin (Country)	*Scientific name*	Colour	SAP (Y/N)	Q A	*α*-carotene	*β*-carotene	*β*-cryptoxanthin	lycopene	lutein	zeaxanthin	Ref
Acerola	BRA	*Malpighia glabra L.*	Red peel		nl=24, nw=2	60 (30-110)	1220 (540-3810)	95 (30-120)		115 (70-160)		44
Acerola	BRA	*Malpighia emarginata DC / Malphigia glabra L.*	reddish-orange	Y	nw=3		573.17 ± 33.21 536.55 ± 27.31*	417.46 ± 17.11		108.03 ± 10.32 99.21 ± 10.21*		45
Acerola	BRA	*Malpighia punicifolia L. var. Olivier*		Y	nl=3, nw=2	14.1 ± 0.8	869.4 ± 41.5	22.1 ± 2.4		48.0 ± 9.5	3.3 ± 0.6	46
Acerola	BRA	*Malpighia punicifolia L. var. Waldy Cati 30*		Y	nl=3, nw=2	7.8 ± 3.3	265.5 ± 92.5	16.3 ± 4.1		70.7 ± 49.6	0.1 ± 0.1	46
Acerola	BRA	*Malpighia punicifolia L., var. Olivier*			VM, nl=2, nw=6		4308 (2486-6130)	<LD				34
Acerola, juice	BRA	*Malpighia glabra L.*			nl=17, nw=2	30 (20-70)	800 (270-1010)	100 (40-100)		50 (20- 60)		44

Acerola, pulp	BRA	*Malpighia glabra L.*			nl=13, nw=2	30 (10-50)	1005 (300-1650)	65 (20-100)		100 (<LD-120)		44
Apple-peach tomato	BRA	*Solanum sessiliflorum*		Y	nw=3	0.45 ± 0.00*	64.35 ± 1.99* 12.87 ± 0.36**	0.72 ± 0.00*				47
Araza	BRA	*Eugenia stipitata McVaugh*			nl=6	64 (31 - 96)	94 (44 - 143)	95 (47 - 142)		455 (154 - 756)	81 (17 - 114)	48
Avocado	PAN	*Persea americana*		Y	nw=4					320 ± 40	<LD	35
Avocado	ESP	*Persea americana*			nw=4	29 ± 1	81 ± 7	40 ± 2	<LD	314 ± 18	<LD	2
Avocado	CRI	*PerseaaAmericana cv. Hass*	green	Y	nl=3, nw=3	76	199	121	28.9	619^		1
Banana	CRI	*Musa paradisiaca cv. Grand naine*	yellow	Y	nl=2, nw=3	56.5	36.9			39.7^		1
Banana	ESP	*Musa paradisiaca L.*		N	nw=3	57.7	69	<LD	<LD	<LD	<LD	2,27
Banana	ESP	*Musa paradisiaca L.*		Y	nw=3	63.1 ± 24	77.3 ± 28	<LD	<LD	7.4 ± 2	<LD	2,27
Black palm	PAN	*Astrocaryum standleyaum*		Y	nw=4					440 ± 30		7
Buriti	BRA	*Mauritia vinifera*					37200* 8700**					49
Cactus pear	MEX	*Opuntia ficus-indica*	green	HPLC	nl=6, nw=3		9733 (7600-11900)			14133 (10200- 18700)		50
Caja	BRA	*Spondias lutea*	Orange	Y	nl=17	107 (79-148)	186 (137-208) 40** (29-50)**	633 (554-819) 61** (37-82)**		523 (352-616)		51
Camu Camu	BRA	*Myrciaria dubia*		Y	nl=6		107.6 (72.8–142.3)	8,4 (6.9–9.9)		381.2* (160.5– 601.9)*	30.5 (22.9-38.0)	35
Canistel	MEX	*Pouteria campechiana*	orange- yellow	N	nw=2		710 ± 70					6

Canistel	PAN	*Pouteria campachiana*		Y	nw=4				<LD	1970 ± 160	7
Caryocar villosum fruits, freeze-dried	BRA	*Caryocar villosum*	yellow	N	nw=3		70 ± 4*		90 ± 20*	290 ± 30*	52
Cashew apple	CRI	*Anacardium occidentale var. Native*	red	Y	nl=3, nw=3	109	935 792*	137	56.0^		1
Cashew apple	BRA	*Anacardium occidentale L.*		Y	nl=3	8	28	30	93	46	53
Cashew apple, concentrated	BRA	*Anacardium occidentale L.*	yellow	N	VM, nl=25	14.99±1.95	14.22 ± 2.15**	6.85 ± 3.56 3.27 ± 0.85**	0.20 ± 0.18		54
Cashew apple, pulp	BRA	*Anacardium occidentale L.*	yellow	N	VM, nl=20	31.81±12.82	16.11 ± 5.39**	35.87 ± 10.88 10.48 ± 2.12**	4.20 ± 2.01		54
Cashew apple, ready-to-drink	BRA	*Anacardium occidentale L.*	yellow	N	VM, nl=5	1.65±1.64	1.96 ± 1.77**	1.81 ± 0.95 0.56 ± 0.17 **	0.56 ± 0.18		54
Cassabanana	PAN	*Sicana odorifera*		Y	nw=4				10 ± 10	40 ± 10	7
Cherry	PAN	*Bunchosia nitida*							750 ± 60	<LD	7
Chinese passion fruit	PAN	*Cionosicyos macranthus*	red						<LD	280 ± 20	55
Chinese rose	PAN	*Pereskia bleo*		Y	nw=4				830 ± 100	80 ± 10	7
Cocona	PAN	*Solanum sessiliflorum*		Y	nw=4				40 ± 20	<LD	7
Corozo	PAN	*Aiphanes aculeate*	yellow-reddish	Y	nw=4				<LD	7920 ± 1030	55
French Plantain, green	PAN	*Musa paradisiaca (AAB)*		Y	nw=4				40 ± 10	<LD	7

French Plantain, ripe	PAN	*Musa paradisiaca (AAB)*		Y	nw=4					150 ± 20	<LD	7
Guava	BRA	*Psidium guajava L. var. Paluma*		N	nl=4, nw=5		378.6 (351.3-432.4)		6794.1 (6999.3-7649.9)			56
Guava	BRA	*Psidium guajava L. var. Paluma*		N	nw=5		366.3 ± 64		6999.3 ± 2420.5			57
Guava	COL	*Psidium guajava L. var. Regional roja*	pink	N	nl=6				2316 (1825-2807)	7 (3-11)		58
Guava	PAN	*Psidium guajava*	yellow	Y	nw=4					40 ± 10	20 ± 10	7
Guava	PAN	*Psidium guajava*	red	Y	nw=4					120 ± 20	<LD	7
Hog plum	CRI	*Spondia purpurea var. Tronador*	red	Y	nl=3, nw=3		73.3 55.9*	24.3		106^		1
Jackfruit	BRA	*Artocarpus heterophyllus/ Batch A*	cream	N	nl=3, nw=2	1.26 (<LD - 2.06)	33.32* (8.33-45.12)* 3.75** (1.06-5.84)**	1.22* (0.67-1.76*)		55.61* (10.36-55.61)*	<LD* (<LD-2.23)*	59
Kiwi	PAN	*Actinidia deliciosa*		Y	nw=4					70 ± 10	<LD	7
Kiwi	ESP	*Actinidia chinensis*	yelow	N	nw=3	<LD	32	<LD	<LD	41	<LD	21
Kiwi	ESP	*Actinidia chinensis*	green	Y	nw=4	<LD	16 ± 3	<LD	<LD	96 ± 17	<LD	2
Mamey	PAN	*Pouteria sapota*	red	Y	nw=4					<LD	<LD	7
Mango	BRA	*Mangifera indica L.var.Tommy Atkins*		N	nl=4, nw=5		1652.3 (1409.1-1557.1)		75.8 (57.4-81.2)			56
Mango	BRA	*Mangifera indica L.var.Tommy Atkins*		N	nw=5		1557.1 ± 180.2		77.2 ± 58.4			57

Mango	PAN	*Mangifera indica*		Y	nw=4					60 ± 10	50 ± 10	7
Mango	MEX	*Mangifera indica L. cv Ataulfo*	reddish-orange	N	nw=2		3197*					60
Mango	MEX	*Mangifera indica L. cv Manila*	reddish-orange	N	nw=2		3558*					60
Mango	CRI	*Mangifera indica L. cv. Tommy Atkins*	Unknown	Y	nl=6, nw=3	19.4	838 762*	12.4	27.1 25.8**	40.9		1
Mango	BRA	*Mangifera indica L. cv. Tommy Atkins*	yellow	Y	nl=3		580 ± 250*	30 ± 10* 10 ± 10 **		60 ± 10	50 ± 10 40 ± 20*	61
Mango	BRA	*Mangifera indica L. cv. Keitt*	yellow	Y	nl=3		670 ± 160*	20 ± 00* 30 ± 20 **			80 ± 30*	61
Mango	BRA	*Mangifera indica L. cv. Keitt*	yellow	Y	nl=3		1510 ± 150*	30 ± 0*			80 ± 20*	62
Mango	ESP	*Magnifera indica L.*	Red-orange	Y	nw=3	<LD	152	<LD	<LD	<LD	<LD	21
Mango	MEX	*Mangifera indica L. cv. Tommy Atkins*					1200					63
Mango	MEX	*Mangifera indica L. cv. Haden*					2800					63
Mango	MEX	*Mangifera indica L. cv. Ataulfo*					1600					63
Mombin	PAN	*Spondias purpurea*	purple	Y	nw=4					630 ± 50	80 ± 10	7
Mombin	PAN	*Spondias mombin*		Y	nw=4					860 ± 70	120 ± 20	7
Mombin	COL	*Spondias mombin*	yellow	Y						630 ± 50	80 ± 10	7

Nance	PAN	*Birsonimia crassiflora*		Y	nw=4				70 ± 10	20 ± 10	7
Naranjilla	PAN	*Solanum quitoense*	yellow-greenish	Y	nw=4				190 ± 30	<LD	7
Papaya	BRA	*Carica papaya L. var. Formosa (control)*		Y	nw=5	548.6 ± 175.1	3798.6 ± 278.0	3137.5 ± 596.3			56
Papaya	BRA	*Carica papaya L. var. Formosa (after preparation)*		Y	nw=5	468.1 ± 224.3	3477.0 ± 1043.7	3131.4 ± 1485.8			56
Papaya	BRA	*Carica papaya L. var. Formosa (during distr.)*		Y	nw=5	598.0 ± 103.4	4097.3 ± 596.9	4281.0 ± 635.6			56
Papaya	BRA	*Carica papaya L. var. Formosa (final distr.)*		Y	nw=5	513.9 ± 256.9	3435.0 ± 1723.2	3105.4 ± 1482.7			56
Papaya	BRA	*Carica papaya L. (Formosa)*	reddish-orange	Y	nl=5, nw=2	120 ± 50*	700 ± 170 670 ± 170*	2300 ± 750 1970 ± 630*			43
Papaya	BRA	*Carica papaya L. (Sunrise)*	reddish-orange	Y	nl=5, nw=2	50 ± 160*	820 ± 120 760 ± 120*	2390 ± 920 2070 ± 790*			43
Papaya	BRA	*Carica papaya L. (Golden)*	orange	Y	nl=5, nw=2	120 ± 30*	870 ± 90 810 ± 90*	1850 ± 640 1630 ± 450*			43
Papaya	BRA	*Carica papaya L. var. Formosa*		N	nw=5	548.6 ± 175.1	3798.6 ± 278	3137.5 ± 596.3			57

Papaya	CRI	*Carica papaya L. commercial line Criolla*	red-fleshed				200 ± 57	191 ± 75 116 ± 31 C 243± 64 L 77 ± 21 M	1981 ± 325* 194 ± 41**		64
Papaya	CRI	*Carica papaya L. commercial F1 hybrid Pococí. marketed as “Papaya Perfecta”*	red-fleshed				514 ± 114	233 ± 15 329± 63 C 899 ± 188 L 218 ± 55 M	3264 ± 362* 436 ± 82**		64
Papaya	CRI	*Carica papaya L. F1 hybrid Industrial 10P*	red-fleshed				534 ± 138	246 ± 67 269 ± 39 C 870 ± 116 L 178 ± 25 M	3861 ± 691* 412 ± 23**		64
Papaya	CRI	*Carica papaya L. F1 hybrid Industrial 10G*	red-fleshed				554 ± 114	296 ± 52 272 ± 49 C 839 ± 148 L 197 ± 35 M	3858 ± 614* 448 ± 83**		64
Papaya	CRI	*Carica papaya L. wild type line Silvestre*	yellow-fleshed				270 ± 79	393 ± 31 229 ± 83 C 747 ± 132 L 271 ± 35 M	12± 5* <LD**		64
Papaya	CRI	*Carica papaya L. line Sunset*	red-fleshed				283 ± 77	160 ± 21 364 ± 69 C 1080 ± 184 L 203 ± 27 M	1861 ± 321* 453 ± 97**		64
Papaya	CRI	*Carica papaya L. line MHR 21-4-6 (cross-breeding of Silvestrex Sunset x Maradol)*	yellow-fleshed				508 ± 80	494 ± 51 540 ± 109 C 1216 ± 226 L 242 ± 22 M	9 ± 5* <LD**		64
Papaya	MEX	*Carica papaya L. cv. Maradol*	reddish-orange	Y	nw=3		230-310	310-800	150-1200		65

Papaya	CRI	*Carica papaya L. cv. Pococi hybrid*	orange	Y	nl=6, nw=3	12.5	358 330*	404	1040*		40.1^	1
Papaya	BRA	*Carica papaya L. cv. Golden*						300*	1300* 100**			66
Papaya	PAN	*Carica papaya L.*	red	Y	nw=4					20 ± 10	60 ± 10	7
Papaya	PAN	*Carica papaya L.*	yellow	Y	nw=4					10 ± 10	<LD	7
Passion fruit	BRA	*Passiflora cincinnata Mast CPAC MJ-26- 01 redondo/ CPAC MJ-26-02 cabaça*	cream				(30-60) ± 10*					67
Passion fruit	BRA	*P. nitida Kunth CPAC MJ-01-03*					5 ± 0*					67
Passion fruit	BRA	*P. setacea D. C. CPAC MJ-12-01-BRS Pérola do Cerrado*	light yellow				66 ± 9* 8 ± 0**					67
Passion fruit	BRA	*P. edulis Sims CPAC MJ-36-01*	deep yellow				284 ± 0.6* 38 ± 0.8**	24 ± 2				67
Passion fruit	BRA	*P. edulis Sims CPAC MJ-21-01*	deep yellow				260 ± 10*	20 ± 3				67
Passion fruit	BRA	*P. edulis Sims.*					570* (360 - 780)* 39** (37 - 40)**	178 (175 - 180)				67
Passion fruit	BRA	*Passiflora edulis var. Flavicarpa*	Yellow-white	Y						10 ± 10	20 ± 10	68

Pejibaye	CRI	*Bactris gasipaes H.B.K.*		Y	nw=6	1369.6 ± 21.4* equiv betaCar	4108.8 ± 72.76* equiv beta-car		69
Pejibaye	BRA	*Bactris gasipaes Kunth*					5600* 600**		49
Pejibaye	CRI	*Bactris gasipaes Kunth*			nl=6		(500-8500)* (100-1300)**		70
Pejibaye	CRI	*Bactris gasipaes Kunth*	orange		nl=2		(3000-5200)* (1400-1600)**		71
Pejibaye fruit	CRI	*Bactris gasipaes var. Bolivia*	red	Y	nw=10	700	8540*	390*	70
Pejibaye fruit	CRI	*Bactris gasipaes var. Darien*	red	Y	nw=10	500	5140*	590*	70
Pejibaye fruit	CRI	*Bactris gasipaes var. Brasil*	red	Y	nw=10	190	1720*	170*	70
Pejibaye fruit	CRI	*Bactris gasipaes var. Costa Rica*	red	Y	nw=10	290	1930*	140*	70
Pejibaye fruit	CRI	*Bactris gasipaes var. Colombia*	light orange	Y	nw=10	120	1590*		70
Pejibaye fruit	CRI	*Bactris gasipaes var. Guatuso*	light yellow	Y	nw=10	30	510*		70
Pejibaye fruit	CRI	*Bactris gasipaes var. Bolivia*	red	Y	nw=10	680	4960*	3970*	70
Pejibaye fruit	CRI	*Bactris gasipaes var. Darien*	red	Y	nw=10	740	4170*	5350*	70
Pejibaye fruit	CRI	*Bactris gasipaes var. Brasil*	red	Y	nw=10	310	1960*	2200*	70
Pejibaye fruit	CRI	*Bactris gasipaes var. Costa Rica*	red	Y	nw=10	340	1510*	1160*	70

Pejibaye fruit	CRI	*Bactris gasipaes var. Colombia*	light orange	Y	nw=10	170	1710*		480*			70
Pejibaye fruit	CRI	*Bactris gasipaes var. Guatuso*	light yellow	Y	nw=10	30	400*		100*			70
Pejibaye. boiled	CRI	*Bactris gasipaes cv. Utilis-Tucurrique*		Y	nl=3, nw=3	4.23	93.2 59.1*		84.2 20.5*	1.55^		1
Persimmon	BRA	*Diospyros kaki L. var. Rama Forte*			VM, nl=2, nw=6		674.42 (645.60-703.24)		510.57 (453.27–567.87)			34
Pineapple	PAN	*Ananas comosus*	yellow	Y	nw=4					10 ± 10	10 ± 10	7
Pineapple	CRI	*Ananas comosus L. cv. MD2*		Y	nl=3, nw=3					0.27^		1
Pinneaple	ESP	*Ananas sativus*	yellow	N	nl=3	<LD	57	<LD	<LD	<LD	<LD	21
Pitanga	BRA	*Eugenia uniflora L.*			nl=20, nw=2		200 (140 - 320)	970 (700 - 1280)	2375* (700-7110)* 235** (40-500)**	210 (120-310)		72
Pitanga. juice	BRA	*Eugenia uniflora L.*			nl=7, nw=2		170 (150-190)	810 (710-910)	2430 (2300-2560)* 230 ± 0.9**	55 (40-70)		72
Pitanga. pulp	BRA	*Eugenia uniflora L.*			nl=2. nw=2		380 ± 0.2	1150 ± 0	1660 ± 0.3* 110 ± 0.1**	100 ± 0		72
Plantain	PAN	*Musa paradisiaca*		Y	nw=4					40 ± 20	<LD	7
Plantain. boiled	CRI	*Musa SSB cv. False horn*	green	Y	nl=3, nw=3	116	192 108*			154^		1

Plantain. boiled	CRI	*Musa SSB cv. False horn*	yellow	Y	nl=3, nw=3	343	644 490*		35.1^		1
Roselle	PAN	*Hibiscus sabdariffa*		Y	nw=4				<LD	80 ± 30	7
Sapote	PAN	*Quararibea cordata*	yellow-orange	Y	nw=4				220 ± 20	4620 ± 620	7
Sastra	PAN	*Garcinia intermedia*	white-yellowish	Y	nw=4		12700 ± 100*		3680 ± 290	8470 ± 750	55
Soncoya	PAN	*Annona purpurea*		Y	nw=4				230 ± 20	680 ± 90	7
Spanish lime	CRI	*Melicocca bijuga var. Native*	Unknown	Y	nl=3, nw=3		73.3 55.9*	24.3	106^		1
Tahitian apple	PAN	*Spondias dulces*		Y	nw=4				50 ± 20	10 ± 10	7
Tree tomato	PAN	*Cyphomandra betacea*	unknown	Y	nw=4				190 ± 10	170 ± 20	7
Tree Tomato	BRA	*Cyphomandra betacea*	Reedish-brown peel	Y	nl=3		620-1280	680-1230	110-170	60-170	73
Tree Tomato	BRA	*Cyphomandra betacea*	orange pulp		nl=3		490-1180	980-1820	100-250	20-110	73
Tree tomato	COL	*Cyphomandra betacea; Solanum betacea*	yellow	Y					190 ± 10	170 ± 20	55
Tree tomato	PAN	*Cyphomandra betacea*	red	Y	nw=4				170 ± 20	240 ± 20	7
Tree tomato	ECU	*Solanum bataceum*	red	Y	nw=3			1580 ± 100	125 ± 5	170 ± 6 Equiv Luteina	74
Tree tomato	ECU	*Solanum bataceum*	yellow	Y	nw=3			1350 ± 100	98 ± 5	59 ± 2 Equiv Luteina	74

Uvaia	BRA	*Eugenia pyriformis Cambess*	500* 200**	75

C – Caprate; L – Laurate; M – Miristate; * *E*-isomers; ** *Z*-isomers; ^ includes zeaxanthin; LD - Limit of detection; VM - validated method; nl - number of lots; nw - number of replicates; Y – Yes; N – No; () - range

Table 13.1. Carotenoids in miscellaneous tropical and sub-tropical fruits (µg/100 g) (cont.)

Name	Origin (Country)	*Scientific name*	Colour	SAP (Y/N)	Q A	phytoene	phytofluene	neoxanthin	violaxanthin	rubixanthin	*δ*-carotene	Ref
Acerola	BRA	*Malpighia glabra L.*	Orange-red peel		nl=24, nw=2			60 (20 - 140)	30 ± 0.3			44
Acerola	BRA	*Malpighia emarginata DC / Malpighia glabra L.*	reddish-orange	Y	nw=3			39.73 ± 1.89	395.33 ± 16.73			45
Acerola	BRA	*Malpighia punicifolia L. var. Olivier*		Y	nl=3, nw=2			6.7 ± 2.6				46
Acerola	BRA	*Malpighia punicifolia L. var. Waldy Cati 30*		Y	nl=3, nw=2			1.8 ± 0.8				46
Acerola, juice	BRA	*Malpighia glabra L.*			nl=5, nw=2				7 (4-10)			44
Acerola, pulp	BRA	*Malpighia glabra L.*			nl=17, nw=2			<LD (<LD - 50)	1 (<LD - 40)			44
Apple-peach tomato	BRA	*Solanum sessiliflorum*		Y	nw=3			4.95 ± 0.27**	8.82 ± 0.90* 0.45 ± 0.00**			47
Arazá	BRA	*Eugenia stipitata McVaugh*			nl=3			16.0 ± 10.2**				48
Caja	BRA	*Spondias lutea*	Orange	Y	nl=17	42 (20 - 49)						51

Camu Camu	BRA	*Myrciaria dubia*		Y	nl=6		12.3 (3.9 - 20.8)	63.8 (12.0 -115.6)	35
Canistel	MEX	*Pouteria campechiana*	orange-yellow	N	nw=2	650 ± 10		19600 ± 500+	6
Caryocar villosum fruits, freeze-dried	BRA	*Caryocar villosum*	yellow	N	nw=3		230 ± 60* 170 ± 40**	110 ± 20* 40 ± 10**	52
Cashew apple	BRA	*Anacardium occidentale L.*		Y	nl=3		136	180	53
Jackfruit	BRA	*Artocarpus heterophyllus*	Cream-yellow	N	nl=3, nw=2		6.33* (5.01 - 17.13)* 5.28 (3.19 - 12.92)**	4.89** (1.79 - 15.54)**	59
Mango	MEX	*Mangifera indica L. cv Ataulfo*	reddish-orange	N	nw=2		748**	1500*	60
Mango	MEX	*Mangifera indica L. cv Manila*	reddish-orange	N	nw=2		1681**	3197*	60
Mango	PAN	*Mangifera indica L. cv. Tommy Atkins*	yellow	Y	nl=3		100 ± 100	2240 ± 910	7
Mango	BRA	*Mangifera indica L. cv. Keitt*	yellow	Y	nl=3		30 ± 20	1800 ± 40	61
Mango	BRA	*Mangifera indica L. cv. Keitt*	yellow	Y	nl=3		210 ± 130	2110 ± 290	62
Passion fruit	BRA	*P. edulis Sims CPAC MJ-36-01*	deep yellow					50 ± 5*	67

Passion fruit	BRA	*P. edulis Sims. Comercial*				55* (50 - 60)*			67
Peach palm	CRI	*Bactris gasipaes H.B.K.*	reddish-orange	Y	nw=6			2020.2 ± 17.12 equiv β-car	69
Pitanga	BRA	*Eugenia uniflora L.*			nl=20, nw=2	265 (210 - 390)	795* (470 - 1150)* 410** (370 - 530)**		72
Pitanga, juice	BRA	*Eugenia uniflora L.*			nl=7, nw=2		1230* (1010-1450)* 350** (320-380)**		72
Pitanga, pulp	BRA	*Eugenia uniflora L.*			nl=2, nw=2		1130 ± 3.8* 310 ± 0.9**		72

* *E*-isomers; ** *Z*-isomers; LD - Limit of detection; VM - validated method; nl - number of lots; nw - number of replicates; Y – Yes; N – No; () - range

Table 13.2. Carotenoids in tropical and sub-tropical fruits (µg/100 g) (cont.)

Name	Origin (Country)	*Scientific name*	Colour	SAP (Y/N)	Q A	γ-carotene	α-cryptoxanthin	antheraxanthin	luteoxanhtin	auroxanthin	zeinoxanthin	Ref
Acerola	BRA	*Malpighia emarginata DC / Malphigia glabra L.*	reddish-orange	Y	nw=3			31.81 ± 1.78		536.55 ± 27.31		45
Avocado	CRI	*Persea americana cv. Hass*	green	Y	nl=3, nw=3					139		1
Banana	CRI	*MuAAA cv. Grand naine*	yellow	Y	nl=2, nw=3					30.5		1

Cactus pear	MEX	*Opuntia ficus-indica*	green	HPLC	nw=3	4500 ± 60					50
Cactus pear	MEX	*Opuntia ficus-indica*	green		nw=3	4900 ± 31					50
Cactus pear	MEX	*Opuntia ficus-indica*	green		nw=3	4600 ± 34					50
Cactus pear	MEX	*Opuntia ficus-indica*	green		nw=3	5200 ± 42					50
Cactus pear	MEX	*Opuntia ficus-indica*	green		nw=3	6800 ± 76					50
Cactus pear	MEX	*Opuntia ficus-indica*	green		nw=3	7100 ± 19					50
Camu Camu	BRA	*Myrciaria dubia*		Y	nl=6			41 (21.5 - 60)			35
Caryocar villosum fruits, freeze-dried	BRA	*Caryocar villosum*	yellow	N	nw=3		340 ± 80* 60 ± 20**				52
Cashew apple	BRA	*Anacardium occidentale L.*		Y	nl=3		26				53
Cashew apple, concentrated	BRA	*Anacardium occidentale L.*	yellow	N	VM, nl=25				0.23 ± 0.14	3.11 ± 2.23	54
Cashew apple, pulp	BRA	*Anacardium occidentale L.*	yellow	N	VM, nl=20				0.62 ± 0.42	7.46 ± 1.82	54
Cashew apple, ready-to-drink	BRA	*Anacardium occidentale L.*	yellow	N	VM, nl=5				0.11 ± 0.04	0.37 ± 0.12	54
Corozo	PAN	*Aiphanes aculeate*	yellow-reddish		nl=3					178 ± 6	7
Jackfruit	BRA	*Artocarpus heterophyllus/ Batch A*	cream	N	nw=2	<LD*	1.64 ± 0.14**	0.77 ± 0.02* <LD**		<LD* <LD**	59
Jackfruit	BRA	*Artocarpus heterophyllus/*	yellow	N	nw=2	<LD*	0.87 ± 0.02**	2.71 ± 0.07* 0.78 ±		2.20± 0.03* 2.10 ± 0.05**	59

		Batch B							0.02**			
Jackfruit	BRA	*Artocarpus heterophyllus/ Batch C*	yellow	N	nw=2		1.24 ± 0.10*	0.98 ± 0.05**	2.38 ± 0.10* <LD**		2.74 ± 0.01* <LD**	59
Mango	PAN	*Mangifera indica L. cv. Tommy Atkins*	yellow	Y	nl=3				200 ± 60			7
Mango	BRA	*Mangifera indica L. cv. Keitt*	yellow	Y	nl=3				270 ± 20			61
Mango	BRA	*Mangifera indica L. cv. Keitt*	yellow	Y	nl=3				380 ± 60			62
Papaya	CRI	*Carica papaya cv. Pococi hybrid*	orange	Y	nl=6, nw=3					330		1
Peach palm	CRI	*Bactris gasipaes H.B.K.*	reddish-orange	Y	nw=6	3248.5 ± 12.84 equiv β-car						69
Peach palm fruit	CRI	*Bactris gasipaes v. Bolivia*	red	Y	nw=10			1340				70
Peach palm fruit	CRI	*Bactris gasipaes v. Darien*	red	Y	nw=10			1630				70
Peach palm fruit	CRI	*Bactris gasipaes v. Brasil*	red	Y	nw=10			330				70
Peach palm fruit	CRI	*Bactris gasipaes v. Costa Rica*	red	Y	nw=10			450				70
Peach palm fruit	CRI	*Bactris gasipaes v. Colombia*	light orange	Y	nw=10			420				70
Peach palm fruit	CRI	*Bactris gasipaes v.*	light yellow	Y	nw=10			110				70

		Guatuso					
Peach palm fruit	CRI	*Bactris gasipaes v. Bolivia*	red	Y	nw=10	2270	70
Peach palm fruit	CRI	*Bactris gasipaes v. Darien*	red	Y	nw=10	2030	70
Peach palm fruit	CRI	*Bactris gasipaes v. Brasil*	red	Y	nw=10	840	70
Peach palm fruit	CRI	*Bactris gasipaes v. Costa Rica*	red	Y	nw=10	520	70
Peach palm fruit	CRI	*Bactris gasipaes v. Colombia*	light orange	Y	nw=10	690	70
Peach palm fruit	CRI	*Bactris gasipaes v. Guatuso*	light yellow	Y	nw=10	160	70

* *E*-isomers; ** *Z*-isomers; LD - Limit of detection; VM - validated method; nl - number of lots; nw - number of replicates; Y – Yes; N – No; () - range

Table 13.3. Carotenoids in miscellaneous tropical and sub-tropical fruits (µg/100 g) (cont.)

Name	Origin (Country)	*Scientific name*	Colour	SAP (Y/N)	Q A	cucurbitaxanthin A	cucurbitaxanthin B	crytoflavin	ζ-carotene	mutatoxanthin	sintaxanthin	neochrome	Ref
Acerola	BRA	*Malpighia emarginata DC / Malphigia glabra L.*	reddish-orange	Y	nw=3		99.21 ± 10.21	36.62 ± 5.90					45
Avocado	CRI	*Persea americana cv. Hass*	green	Y	nl=3, nw=3			60.1					1
Banana	CRI	*MuAAA cv. Grand naine*	yellow	Y	nl=2, nw=3			6.6					1

Camu Camu	BRA	*Myrciaria dubia*		Y	nl=3					1.11 ± 0.4		35
Camu Camu	BRA	*Myrciaria dubia*		Y	nl=3					1.0 ± 0.3		35
Canistel	MEX	*Pouteria campechiana*	orange-yellow	N	nw=2			910 ± 30*				6
Caryocar villosum fruits. freeze-dried	BRA	*Caryocar villosum*	yellow	N	nw=3				60 ± 50**			52
Cashew apple. concentrated	BRA	*Anacardium occidentale L.*	yellow	N	VM, nl=25			1.09 ± 0.56				54
Cashew apple. pulp	BRA	*Anacardium occidentale L.*	yellow	N	VM, nl=20			2.60 ± 0.85				54
Jackfruit	BRA	*Artocarpus heterophyllus*	cream-yellow	N	nl=2, nw=2						<LD* (<LD - 2.05)*	59
Papaya	CRI	*Carica papaya cv. Pococi hybrid*	orange	Y	nl=6, nw=3	1040	27.5					1
Passion fruit	BRA	*P. edulis sims CPAC MJ-36-01*	deep yellow					540 ± 28* 628 ± 15**				67
Passion fruit	BRA	*P. edulis Sims CPAC MJ-21-01*	deep yellow					1095 ± 30* 1210 ± 70**				67
Passion fruit	BRA	*P. edulis Sims.*						685* (230-1140)* 442** (200-683)**				67
Peach palm fruit	CRI	*Bolivia*	red	Y	nw=10			9560* 5220**				70

Peach palm fruit	CRI	*Darien*	red	Y	nw=10	5350* 5150**	70
Peach palm fruit	CRI	*Brasil*	red	Y	nw=10	1550* 1600**	70
Peach palm fruit	CRI	*Costa Rica*	red	Y	nw=10	2000* 13200**	70
Peach palm fruit	CRI	*Colombia*	light orange	Y	nw=10	920* 420**	70
Peach palm fruit	CRI	*Guatuso*	light yellow	Y	nw=10	190* 130**	70
Peach palm fruit	CRI	*Bolivia*	red	Y	nw=10	7240* 1550**	70
Peach palm fruit	CRI	*Darien*	red	Y	nw=10	6060* 780**	70
Peach palm fruit	CRI	*Brasil*	red	Y	nw=10	2170* 1100**	70
Peach palm fruit	CRI	*Costa Rica*	red	Y	nw=10	1960* 430**	70
Peach palm fruit	CRI	*Colombia*	light orange	Y	nw=10	1170* 820**	70
Peach palm fruit	CRI	*Guatuso*	light yellow	Y	nw=10	180* 80**	70

* *E*-isomers; ** *Z*-isomers; LD - Limit of detection; VM - validated method; nl - number of lots; nw - number of replicates; Y – Yes; N – No; () - range

Table 14. Carotenoids in starchy roots (µg/100 g)

Name (english)	Origin (Country)	*Scientific name*	Processing	SAP (Y/N)	QA	*β*-carotene	*β*-cryptoxanthin	lycopene	lutein	zeaxanthin	β-carotene-5,6-epoxide	Ref
Cassava	ESP	*Manihot esculenta Cranzt CM 2772-3*	Raw	N	nw=3	370 ± 6						76
Cassava	ESP	*Manihot esculenta Cranzt MBRA*	Raw	N	nw=3	298 ± 25						76

		1324					
Cassava	ESP	*Manihot esculenta Cranzt MCOL 2401*	Raw	N	nw=3	303 ± 66	76
Cassava	ESP	*Manihot esculenta Cranzt*	Raw	N	nl=3, nw=3	1034	76
Cassava	ESP	*Manihot esculenta Cranzt*	Gari	N	nl=3, nw=3	332	76
Cassava	ESP	*Manihot esculenta Cranzt*	Boiled	N	nl=3, nw=3	614	76
Cassava	ESP	*Manihot esculenta Cranzt*	Oven dried	N	nl=3, nw=3	740	76
Cassava	ESP	*Manihot esculenta Cranzt*	Oven dried, flour, 2 weeks	N	nl=3, nw=3	417	76
Cassava	ESP	*Manihot esculenta Cranzt*	Oven dried, flour, 4 weeks	N	nl=3, nw=3	371	76
Cassava	ESP	*Manihot esculenta Cranzt*	Oven dried, flour, vacum, 2 weeks	N	nl=3, nw=3	421	76
Cassava	ESP	*Manihot esculenta Cranzt*	Oven dried, flour, vacum, 4 weeks	N	nl=3, nw=3	332	76
Cassava	ESP	*Manihot esculenta Cranzt*	Sun dried	N	nl=3, nw=3	374	76

Cassava	ESP	*Manihot esculenta Cranzt*	Sun dried, flour, 2 weeks	N	nl=3, nw=3	217	76
Cassava	ESP	*Manihot esculenta Cranzt*	Sun dried, flour, 4 weeks	N	nl=3, nw=3	176	76
Cassava	ESP	*Manihot esculenta Cranzt*	Sun dried, flour, vacum, 2 weeks	N	nl=3, nw=3	185	76
Cassava	ESP	*Manihot esculenta Cranzt*	Sun dried, flour, vacum, 4 weeks	N	nl=3, nw=3	171	76
Cassava	ESP	*Manihot esculenta Cranzt*	Sun dried, slices, 2 weeks	N	nl=3, nw=3	230	76
Cassava	ESP	*Manihot esculenta Cranzt*	Sun dried, slices, 4 weeks	N	nl=3, nw=3	179	76
Cassava	ESP	*Manihot esculenta Cranzt*	Shadow-dried	N	nl=3, nw=3	598	76
Cassava	CRI	*Yucca schidigera cv. Valencia*	Boiled	Y	nl=5, nw=3	13.4 7.26*	1
Cassava	COL	*Manihot esculenta. var. IAC 576-70*	Raw		nl=3	260 ± 2	77
Cassava	BRA	*Manihot esculenta Crantz / 1456 - Vermelhinha*	Raw	N	nw=3	199 ± 9 100 ± 5* 99 ± 4**	78
Cassava	BRA	*Manihot esculenta Crantz / 1153 - Klainasik*	Raw	N	nw=3	329 ± 6 167 ± 1* 163 ± 6**	78

Cassava	BRA	*Manihot esculenta Crantz / 1668 - Cacau amarelo*	Raw	N	nw=3	211± 2 101 ± 1 * 110 ± 2**	78
Cassava	BRA	*Manihot esculenta Crantz / 1692 - Dendê*	Raw	N	nw=3	238 ± 14 171 ± 11* 67 ± 29**	78
Cassava	BRA	*Manihot esculenta Crantz / 1721 - Aipim cacau*	Raw	N	nw=3	284 ± 35 158 ± 16* 126 ± 18**	78
Cassava	BRA	*Manihot esculenta Crantz / Hibrido 14-08*	Raw	N	nw=3	811 ± 6 727 ± 5* 85 ± 2**	78
Cassava	BRA	*Manihot esculenta Crantz / Hibrido 14-11*	Raw	N	nw=3	537 ± 51 423 ± 47* 113 ± 4**	78
Cassava	COL	*Manihot esculenta Crantz (2006)*	Raw	N	nl=288	230 (max-990)	79
Cassava	COL	*Manihot esculenta Crantz (2007)*	Raw	N	nl=173	550 (max-1280)	79
Cassava	COL	*Manihot esculenta Crantz (2009)*	Raw	N	nl=345	490 (max-1030)	79
Cassava	COL	*Manihot esculenta Crantz (2010)*	Raw	N	nl=490	980 (max-1910)	79
Cassava	COL	*Manihot esculenta Crantz (2011)*	Raw	N	nl=332	850 (max-1500)	79

Cassava	COL	*Manihot esculenta Crantz (2012)*	Raw	N	nl=415	860 (max-1620)						79
Sweet potato	PAN	*Ipomoea batatas*	Raw	Y	nw=4				90 ± 10	30 ± 10		7
Sweet potato	CRI	*Ipomoea batata cv. Guapileño*	Boiled	Y	VM	496 377*	14.9	58.5**	27.1^			1
Sweet Potato	COL	*Ipomoea batatas, var. Resisto*	Raw		n=3	12700 ± 10 1840 ± 70*						77
Sweet Potato	COL	*Ipomoea batatas. var. Brasilia*	Raw		VM	1150 ± 30						77
Sweet potato	BRA	*Ipomoea batatas Lam., CNPH 1007*	Raw	Y	nw=30	79100 ± 4600*^{dw} 14200 ± 300**^{dw}			100 ± 0^{dw}	100 ± 0^{dw}	7000 ± 200^{dw}	80
Sweet potato	BRA	*Ipomoea batatas Lam., CNPH 1007*	Boiled	Y	nw=30	68900 ± 4500*^{dw} 8200 ± 100**dw			400 ± 0^{dw}	300 ± 0^{dw}	8000 ± 100^{dw}	80
Sweet potato	BRA	*Ipomoea batatas Lam., CNPH 1007*	Roasted	Y	nw=30	64600 ± 1600*^{dw} 11600 ± 200**^{dw}			100 ± 0^{dw}	100 ± 0^{dw}	7000 ± 500^{dw}	80
Sweet potato	BRA	*Ipomoea batatas Lam., CNPH 1007*	Steamed	Y	nw=30	69400 ± 1200*^{dw} 11300 ± 500**^{dw}			200 ± 0^{dw}	100 ± 0^{dw}	7600 ± 100^{dw}	80
Sweet potato	BRA	*Ipomoea batatas Lam., CNPH 1007*	Flour	Y	nw=30	45400 ± 2800*^{dw} 4700 ± 400**^{dw}			100 ± 0^{dw}	100 ± 0^{dw}	3800 ± 300^{dw}	80
Sweet potato	BRA	*Ipomoea batatas Lam., CNPH 1194*	Raw	Y	nw=30	128500 ± 2200*^{dw} 15400 ± 500**^{dw}			400±100^{dw}	200 ± 0^{dw}	11300 ± 200^{dw}	80

Sweet potato	BRA	*Ipomoea batatas Lam,. CNPH 1194*	Boiled	Y	nw=30	133300 ± 5000*^{dw} 14600 ± 1200**^{dw}		400±100^{dw}	200 ± 100^{dw}	13100 ± 400^{dw}	80
Sweet potato	BRA	*Ipomoea batatas Lam., CNPH 1194*	Roasted	Y	nw=30	127000 ± 7900*^{dw} 16600 ± 1300**^{dw}		300 ± 0^{dw}	200 ± 0^{dw}	9600 ± 600^{dw}	80
Sweet potato	BRA	*Ipomoea batatas Lam.. CNPH 1194*	Steamed	Y	nw=30	131000 ± 1900*^{dw} 15900 ± 300**^{dw}		1100 ± 0^{dw}	600 ± 0^{dw}	15400 ± 200^{dw}	80
Sweet potato	BRA	*Ipomoea batatas Lam., CNPH 1194*	Flour	Y	nw=30	79700 ± 5500*^{dw} 6800 ± 200**^{dw}		300 ± 0^{dw}	200 ± 0^{dw}	6500 ± 500^{dw}	80
Sweet potato	BRA	*Ipomoea batatas Lam,. CNPH 1202*	Raw	Y	nw=30	84600 ± 1600*^{dw} 14300 ± 600**^{dw}		200 ± 0^{dw}	100 ± 0^{dw}	8400 ± 100^{dw}	80
Sweet potato	BRA	*Ipomoea batatas Lam,. CNPH 1202*	Boiled	Y	nw=30	70600 ± 2700*^{dw} 13200 ± 1100**^{dw}		200 ± 0^{dw}	100 ± 0^{dw}	8600 ± 500^{dw}	80
Sweet potato	BRA	*Ipomoea batatas Lam., CNPH 1202*	Roasted	Y	nw=30	66500 ± 5200*^{dw} 8100 ± 700**^{dw}		600±100^{dw}	400 ± 0^{dw}	8400 ± 500^{dw}	80
Sweet potato	BRA	*Ipomoea batatas Lam., CNPH 1202*	Steamed	Y	nw=30	77100 ± 1800*^{dw} 13400 ± 300**^{dw}		200 ± 0^{dw}	100 ± 0^{dw}	8900 ± 200^{dw}	80
Sweet potato	BRA	*Ipomoea batatas Lam., CNPH 1202*	Flour	Y	nw=30	59200 ± 2300*^{dw} 5500 ± 300**^{dw}		200 ± 0^{dw}	100 ± 0^{dw}	5300 ± 100^{dw}	80
Sweet potato	BRA	*Ipomoea batatas Lam., CNPH 1205*	Raw	Y	nw=30	120100 ± 7700*^{dw} 15500 ± 1000**^{dw}		100 ± 0^{dw}	100 ± 0^{dw}	8900 ± 400^{dw}	80

Sweet potato	BRA	*Ipomoea batatas Lam,. CNPH 1205*	Boiled	Y	nw=30	76900 ± 4400*^{dw} 10400 ± 100**^{dw}			200 ± 0^{dw}	200 ± 0^{dw}	7800 ± 100^{dw}	80
Sweet potato	BRA	*Ipomoea batatas Lam., CNPH 1205*	Roasted	Y	nw=30	94500 ± 7700*^{dw} 15300 ± 1500**^{dw}			100 ± 0^{dw}	100 ± 0^{dw}	8800 ± 900^{dw}	80
Sweet potato	BRA	*Ipomoea batatas Lam., CNPH 1205*	Steamed	Y	nw=30	103000 ± 9000*^{dw} 14700 ± 200**^{dw}			100 ± 0^{dw}	100 ± 0^{dw}	9500 ± 300^{dw}	80
Sweet potato	BRA	*Ipomoea batatas Lam., CNPH 1205*	Flour	Y	nw=30	56300 ± 3500*^{dw} 2900 ± 0**^{dw}			100 ± 0^{dw}	100 ± 0^{dw}	3800 ± 100^{dw}	80

^{dw} - dry weight basis; * *E*-isomers; ** *Z*-isomers; ^ includes zeaxanthin; LD - Limit of detection; VM - validated method; nl - number of lots; nw - number of replicates; Y – Yes; N – No; () - range

Table 15. Carotenoids in starchy tubers (µg/100 g)

Name	Origin (Country)	Scientific name	Colour	Process	peel	SAP (Y/N)	QA	*β*-carotene	lutein	zeaxanthin	neoxanthin	violaxanthin	antheraxanthin	Ref
Potato	PAN	*Solanum tuberosum*		Raw		Y	nw=4		70 ± 10	770 ± 60				7
Potato	ESP	*Solanum tuberosum subsp. Tuberosum Cazona*	yellow (flesh)	Freeze-dried	without	Y	nw=3	1.3 ± 0.1^{dw}	27.2 ± 1.8^{dw}		11.7 ± 1.4^{dw}	8.2 ± 0.9^{dw}	2.2 ± 0.3^{dw}	81
Potato	ESP	*Solanum tuberosum subsp. Andigena Morada*	yellow	Freeze-dried	without	Y	nw=3	2.1 ± 0.1^{dw}	14.3 ± 0.6^{dw}		17.6 ± 0.5^{dw}	12.7 ± 0.4^{dw}	3.1 ± 0.1^{dw}	81
Potato	ESP	*Solanum tuberosum subsp. Tuberosum Fina de carvalho*	yellow	Freeze-dried	without	Y	nw=3	2.6 ± 0.0^{dw}	43.9 ± 1.1^{dw}		15.1 ± 0.5^{dw}	6.1 ± 0.1^{dw}	4.4 ± 0.2^{dw}	81
Potato	ESP	*Solanum tuberosum subsp. Tuberosum Maika*	light yellow	Freeze-dried	without	Y	nw=3	3.2 ± 0.1^{dw}	36.9 ± 0.5^{dw}		22.4 ± 0.7^{dw}	9.1 ± 0.1^{dw}	4.9 ± 0.1^{dw}	81

Potato	ESP	*Solanum tuberosum subsp. Andigena Jesus*	purple and white	Freeze-dried	without	Y	nw=3	3.0 ± 0.1^{dw}	33.4 ± 2.2^{dw}		28.6 ± 1.8^{dw}	8.6 ± 0.4^{dw}	4.5 ± 0.3^{dw}	81
Potato	ESP	*Solanum tuberosum subsp. Tuberosum Zorba*	yellow	Freeze-dried	without	Y	nw=3	0.2 ± 0.0^{dw}	6.2± 0.0^{dw}		36.2 ± 0.4^{dw}	18 ± 0.3^{dw}	3.4 ± 0.1^{dw}	81
Potato	ESP	*Solanum tuberosum subsp. Tuberosum Emp06-134*	purple and white	Freeze-dried	without	Y	nw=3	8.3 ± 0.2^{dw}	38.7 ± 0.6^{dw}		27.7 ± 0.3^{dw}	14.1 ± 0.2^{dw}	5.7 ± 0.1^{dw}	81
Potato	ESP	*Solanum tuberosum subsp. Tuberosum Tramontana*	yellow	Freeze-dried	without	Y	nw=3	0.2 ± 0.0^{dw}	12.5 ± 2.2^{dw}		17.8 ± 2.6^{dw}	44.3 ± 6.2^{dw}	6.1 ± 1.3^{dw}	81
Potato	ESP	*Solanum tuberosum subsp. Tuberosum Arrow*	light yellow	Freeze-dried	without	Y	nw=3	8.0 ± 0.2^{dw}	50.2 ± 1.3^{dw}		24.5 ± 1.0^{dw}	20.7 ± 0.9^{dw}	7.3 ± 0.4^{dw}	81
Potato	ESP	*Solanum tuberosum subsp. Tuberosum Kenebec*	light yellow	Freeze-dried	without	Y	nw=3	4.7 ± 0.4^{dw}	58.9 ± 3.4^{dw}		39.2 ± 3.8^{dw}	10.9 ± 0.6^{dw}	5.9 ± 0.2^{dw}	81
Potato	ESP	*Solanum tuberosum subsp. Tuberosum Desiree*	yellow	Freeze-dried	without	Y	nw=3	0.2 ± 0.0^{dw}	21.8 ± 0.9^{dw}		42.1 ± 1.5^{dw}	16.7 ± 0.6^{dw}	8.7 ± 0.4^{dw}	81
Potato	ESP	*Solanum tuberosum subsp. Andigena Puca Quitish*	purple and white	Freeze-dried	without	Y	nw=3	9.2 ± 0.4^{dw}	40.0 ± 1.7^{dw}		28.3 ± 0.6^{dw}	11.0 ± 0.4^{dw}	5.8 ± 0.2^{dw}	81
Potato	ESP	*Solanum tuberosum subsp. Tuberosum Victor*	yellow	Freeze-dried	without	Y	nw=3	6.8 ± 0.3^{dw}	54.5 ± 4.1^{dw}		37.5 ± 1.4^{dw}	34.1 ± 0.6^{dw}	10.2 ± 0.0^{dw}	81
Potato	ESP	*Solanum tuberosum subsp. Tuberosum Opal*	light yellow	Freeze-dried	without	Y	nw=3	0.3 ± 0.0^{dw}	16.7 ± 1.9^{dw}		59.1 ± 4.9^{dw}	53.6 ± 5.4^{dw}	8.1 ± 0.6^{dw}	81
Potato	ESP	*Solanum tuberosum subsp. Tuberosum Red Pontiac*	light yellow	Freeze-dried	without	Y	nw=3	4.7 ± 0.0^{dw}	89.3 ± 1.3^{dw}		34.8 ± 0.2^{dw}	14.1 ± 0.1^{dw}	10.8 ± 0.3^{dw}	81

Potato	ESP	*Solanum tuberosum subsp. Andigena Negrita*	white and purple	Freeze-dried	without	Y	nw=3	6.2 ± 0.2^{dw}	38.6 ± 1.3^{dw}		29.3 ± 1.7^{dw}	9.6 ± 0.6^{dw}	7.4 ± 0.4^{dw}	81
Potato	ESP	*Solanum tuberosum subsp. Tuberosum Elodie*	yellow	Freeze-dried	without	Y	nw=3	0.3 ± 0.0^{dw}	53.9 ± 2.4^{dw}		64.5 ± 3.5^{dw}	24.3 ± 0.9^{dw}	9.2 ± 0.1^{dw}	81
Potato	ESP	*Solanum tuberosum subsp. Goniacalix kashpadama amarilla*	light yellow	Freeze-dried	without	Y	nw=3	12.4 ± 1.3^{dw}	112.2 ± 11.3^{dw}		34.6 ± 2.1^{dw}	19.9 ± 0.8^{dw}	12.6 ± 0.2^{dw}	81
Potato	ESP	*Solanum tuberosum subsp. Andigena Kasta*	purple and white	Freeze-dried	without	Y	nw=3	9.7 ± 0.4^{dw}	55.0 ± 1.0^{dw}		53.5 ± 1.3^{dw}	15.5 ± 0.1^{dw}	5.0 ± 0.2^{dw}	81
Potato	ESP	*Solanum tuberosum subsp. Stenotonum Morar Nayra Mari*	purple and yellow	Freeze-dried	without	Y	nw=3	13.3 ± 1.1^{dw}	102.9± 5.8^{dw}		66.7 ± 5.4^{dw}	18.9 ± 1.3^{dw}	14.8 ± 1.4^{dw}	81
Potato	ESP	*Solanum tuberosum subsp. Stenotonum V*	yellow	Freeze-dried	without	Y	nw=3	7.3 ± 0.4^{dw}	68.5 ± 7.8^{dw}		69.5 ± 8.7^{dw}	81.1 ± 10.3^{dw}	15.9 ± 1.6^{dw}	81
Potato	ESP	*Solanum tuberosum subsp. Tuberosum Spunta*	yellow	Freeze-dried	without	Y	nw=3	0.6 ± 0.1^{dw}	31.2 ± 1.2^{dw}		72.4 ± 3.4^{dw}	122.5 ± 7.2^{dw}	13.2 ± 1.1^{dw}	81
Potato	ESP	*Solanum tuberosum subsp. Tuberosum Fina de Gredos*	light yellow	Freeze-dried	without	Y	nw=3	1.1 ± 0.1^{dw}	35.3 ± 0.4^{dw}		57.8 ± 0.4^{dw}	72.9 ± 0.7^{dw}	9.2 ± 0.0^{dw}	81
Potato	ESP	*Solanum tuberosum subsp. Andigena Muro Shocco*	purple and white	Freeze-dried	without	Y	nw=3	22.3 ± 0.7^{dw}	87.0 ± 0.2^{dw}		81.4 ± 0.4^{dw}	42.2 ± 1.0^{dw}	12.6 ± 0.3^{dw}	81
Potato	ESP	*Solanum tuberosum subsp. Andigena Morada Turuna*	yellow	Freeze-dried	without	Y	nw=3	21.1 ± 0.8^{dw}	180.9 ± 1.0^{dw}		41.6 ± 0.9^{dw}	39.1 ± 1.3^{dw}	19.8 ± 0.2^{dw}	81
Potato	ESP	*Solanum tuberosum subsp. Tuberosum Arene*	yellow	Freeze-dried	without	Y	nw=3	0.9 ± 0.0^{dw}	77.2± 3.8^{dw}		63.9 ± 3.0^{dw}	143.8 ± 4.6^{dw}	16.5 ± 0.5^{dw}	81

Potato	ESP	*Solanum tuberosum subsp. Tuberosum Cherie*	yellow	Freeze-dried	without	Y	nw=3	0.3 ± 0.0^{dw}	49.6 ± 2.3^{dw}		81.1 ± 3.2^{dw}	129.4 ± 5.8^{dw}	11.0 ± 0.6^{dw}	81
Potato	ESP	*Solanum tuberosum subsp. Tuberosum Mirari*	yellow	Freeze-dried	without	Y	nw=3	1.6 ± 0.1^{dw}	53.4 ± 2.4^{dw}		63.1 ± 3.2^{dw}	183.6 ± 12.0^{dw}	27.5 ± 2.1^{dw}	81
Potato	ESP	*Solanum tuberosum subsp. Tuberosum Buesa*	yellow	Freeze-dried	without	Y	nw=3	1.5 ± 0.1^{dw}	51.7 ± 0.2^{dw}		42.1 ± 1.0^{dw}	132.9 ± 5.3^{dw}	24.1 ± 0.3^{dw}	81
Potato	ESP	*Solanum tuberosum subsp. Tuberosum Zafira*	yellow	Freeze-dried	without	Y	nw=3	1.0 ± 0.0^{dw}	43.9 ± 0.2^{dw}		103.8 ± 0.3^{dw}	203.0 ± 1.4^{dw}	17.1 ± 0.8^{dw}	81
Potato	ESP	*Solanum tuberosum subsp. Tuberosum Corine*	light yellow	Freeze-dried	without	Y	nw=3	2.4 ± 0.1^{dw}	51.0 ± 2.1^{dw}		59.4 ± 1.4^{dw}	177.5 ± 7.8^{dw}	13.5 ± 0.2^{dw}	81
Potato	ESP	*Solanum tuberosum subsp. Tuberosum Onda*	yellow	Freeze-dried	without	Y	nw=3	1.3 ± 0.1^{dw}	52.2 ± 0.5^{dw}		62.0 ± 2.4^{dw}	184.5 ± 7.2^{dw}	18.5 ± 0.3^{dw}	81
Potato	ESP	*Solanum tuberosum subsp. Tuberosum Alegria oro*	yellow	Freeze-dried	without	Y	nw=3	0.9 ± 0.0^{dw}	36.3 ± 0.5^{dw}		61.9 ± 1.4^{dw}	143.0^{dw}	15.9 ± 0.3^{dw}	81
Potato	ESP	*Solanum tuberosum subsp. Tuberosum Monalisa*	yellow	Freeze-dried	without	Y	nw=3	1.1 ± 0.1^{dw}	32.9 ± 5.0^{dw}		81.4 ± 12.1^{dw}	99.6 ± 16.1^{dw}	14.6 ± 2.7^{dw}	81
Potato	ESP	*Solanum tuberosum subsp. Tuberosum Roja riñón*	yellow	Freeze-dried	without	Y	nw=3	0.7 ± 0.1^{dw}	67.0 ± 2.3^{dw}		61.5 ± 3.1^{dw}	202.7 ± 11.5^{dw}	22.0 ± 2.0^{dw}	81
Potato	ESP	*Solanum tuberosum subsp. Tuberosum Iker*	yellow	Freeze-dried	without	Y	nw=3	1.6 ± 0.0^{dw}	33.9 ± 0.9^{dw}		94.3 ± 3.0^{dw}	115.5 ± 2.9^{dw}	15.4 ± 0.9^{dw}	81
Potato	ESP	*Solanum tuberosum subsp. Tuberosum Zela*	yellow	Freeze-dried	without	Y	nw=3	4.0 ± 0.2^{dw}	74.0 ± 9.8^{dw}		76.9 ± 8.8^{dw}	182.9 ± 18.4^{dw}	21.7 ± 2.2^{dw}	81

Potato	ESP	*Solanum tuberosum subsp. Tuberosum Zadorra*	yellow	Freeze-dried	without	Y	nw=3	2.3 ± 0.2^{dw}	70.2 ± 5.9^{dw}		47.8 ± 1.4^{dw}	270.4 ± 13.7^{dw}	31.6 ± 1.2^{dw}	81
Potato	ESP	*Solanum tuberosum subsp. Tuberosum Duquesa*	yellow	Freeze-dried	without	Y	nw=3	2.5 ± 0.3^{dw}	55.4 ± 2.6^{dw}		44.2 ± 2.6^{dw}	262.9 ± 9.7^{dw}	30.1 ± 2.1^{dw}	81
Potato	ESP	*Solanum tuberosum subsp. Tuberosum Zunta*	yellow	Freeze-dried	without	Y	nw=3	2.1 ± 0.3^{dw}	47.3 ± 2.3^{dw}		52.8 ± 2.1^{dw}	258.3 ± 8.5^{dw}	19.3 ± 1.6^{dw}	81
Potato	ESP	*Solanum tuberosum subsp. Tuberosum Sofia*	yellow	Freeze-dried	without	Y	nw=3	1.5 ± 0.1^{dw}	59.2 ± 4.8^{dw}		70.2 ± 5.6^{dw}	239.7 ± 21.7^{dw}	19.1 ± 2.4^{dw}	81
Potato	ESP	*Solanum tuberosum subsp. Tuberosum Nagore*	yellow	Freeze-dried	without	Y	nw=3	1.8 ± 0.1^{dw}	37.3 ± 0.2^{dw}		139.2 ± 2.5^{dw}	171.1 ± 2.9^{dw}	13.9 ± 0.7^{dw}	81
Potato	ESP	*Solanum tuberosum subsp. Tuberosum Ambition*	yellow	Freeze-dried	without	Y	nw=3	2.7 ± 0.0^{dw}	72.4 ± 3.7^{dw}		123.7 ± 1.7^{dw}	152.1 ± 2.7^{dw}	24.3 ± 0.3^{dw}	81
Potato	ESP	*Solanum tuberosum subsp. Tuberosum Stemster*	yellow	Freeze-dried	without	Y	nw=3	4.5 ± 0.1^{dw}	56.2 ± 1.9^{dw}		95.2 ± 3.7^{dw}	255.3 ± 5.4^{dw}	21.7 ± 1.1^{dw}	81
Potato	ESP	*Solanum tuberosum subsp. Tuberosum Emp06-133*	yellow and maroon	Freeze-dried	without	Y	nw=3	4.3 ± 0.1^{dw}	106.4 ± 0.6^{dw}		114.7 ± 1.5^{dw}	219.6 ± 2.5^{dw}	39.4 ± 0.5^{dw}	81
Potato	ESP	*Solanum tuberosum subsp. Tuberosum Pedro Muñoz*	yellow	Freeze-dried	without	Y	nw=3	5.8 ± 0.2^{dw}	62.6 ± 0.1^{dw}		140.3 ± 0.9^{dw}	81.3 ± 0.7^{dw}	14.8 ± 0.0^{dw}	81
Potato	ESP	*Solanum tuberosum subsp. Tuberosum*	yellow	Freeze-dried	without	Y	nw=3	1.2 ± 0.1^{dw}	91.4 ± 7.4^{dw}		143.6 ± 7.1^{dw}	234.8 ± 9.7^{dw}	21.5 ± 0.9^{dw}	81

		Murato												
Potato	ESP	*Solanum tuberosum subsp. Tuberosum Harana*	yellow	Freeze-dried	without	Y	nw=3	3.9 ± 0.3^{dw}	88.5 ± 1.5^{dw}		111.9 ± 2.6^{dw}	213.7 ± 2.7^{dw}	36.2 ± 1.5^{dw}	81
Potato	ESP	*Solanum tuberosum subsp. Tuberosum Nerea*	yellow	Freeze-dried	without	Y	nw=3	0.6 ± 0.0^{dw}	77.4 ± 4.2^{dw}		127.3 ± 4.9^{dw}	286.9 ± 10.7^{dw}	22.8 ± 1.3^{dw}	81
Potato	ESP	*Solanum tuberosum subsp. Tuberosum Montico*	light yellow	Freeze-dried	without	Y	nw=3	2.6 ± 0.1^{dw}	84.2 ± 3.4^{dw}		57.0 ± 2.0^{dw}	314.5 ± 14.8^{dw}	31.6 ± 0.6^{dw}	81
Potato	ESP	*Solanum tuberosum subsp. Tuberosum Leire*	yellow	Freeze-dried	without	Y	nw=3	2.5 ± 0.1^{dw}	105.6 ± 5.3^{dw}		63.9 ± 7.3^{dw}	282.4 ± 20.5^{dw}	63.2 ± 4.7^{dw}	81
Potato	ESP	*Solanum tuberosum subsp. Tuberosum Romula*	yellow	Freeze-dried	without	Y	nw=3	4.2 ± 0.2^{dw}	101.2 ± 5.1^{dw}		189.3 ± 13.3^{dw}	331.6 ± 25.0^{dw}	29.0 ± 1.0^{dw}	81
Potato	ESP	*Solanum tuberosum subsp. Tuberosum Miranda*	yellow	Freeze-dried	without	Y	nw=3	6.3 ± 0.5^{dw}	130.6 ± 7.5^{dw}		137.2 ± 5.1^{dw}	255.9 ± 14.8^{dw}	36.4 ± 1.6^{dw}	81
Potato	ESP	*Solanum tuberosum subsp. Tuberosum Ibenca*	yellow	Freeze-dried	without	Y	nw=3	6.6 ± 0.4^{dw}	140.3 ± 7.9^{dw}		79.4 ± 3.8^{dw}	276.9 ± 9.4^{dw}	27.9 ± 1.0^{dw}	81
Potato	ESP	*Solanum tuberosum subsp. Tuberosum Ayala*	yellow	Freeze-dried	without	Y	nw=3	3.4± 0.0^{dw}	104.8 ± 4.8^{dw}		125.1 ± 0.4^{dw}	350.8 ± 9.9^{dw}	53.1 ± 2.1^{dw}	81
Potato	ESP	*Solanum tuberosum subsp. Tuberosum Marfona*	yellow	Freeze-dried	without	Y	nw=3	3.8 ± 0.1^{dw}	93.5 ± 4.3^{dw}		272.8 ± 22.3^{dw}	219.1 ± 10.6^{dw}	28.4 ± 1.7^{dw}	81
Potato	ESP	*Solanum tuberosum subsp. Tuberosum Agria*	yellow	Freeze-dried	without	Y	nw=3	2.9 ± 0.2^{dw}	97.5 ± 5.1^{dw}		124.3 ± 3.3^{dw}	292.6 ± 6.3^{dw}	22.8 ± 0.1^{dw}	81

Potato	ESP	*Solanum tuberosum subsp. Andigena Sipancachi*	yellow	Freeze-dried	without	Y	nw=3	7.4 ± 0.7^{dw}	102.9 ± 9.9^{dw}		106.5 ± 6.5^{dw}	330.9 ± 30.8^{dw}	28.4 ± 3.7^{dw}	81
Potato	ESP	*Solanum tuberosum subsp. Stenotonum Poluya*	yellow with maroon spots	Freeze-dried	without	Y	nw=3	13.6 ± 1.4^{dw}	91.0 ± 6.1^{dw}		206.0 ± 8.4^{dw}	248.8 ± 11.3^{dw}	51.2 ± 2.4^{dw}	81
Potato	ESP	*Solanum tuberosum subsp. Phureja Chaucha*	yellow with purple spots	Freeze-dried	without	Y	nw=3	9.1 ± 1.7^{dw}	143.8 ± 8.6^{dw}		175.2 ± 7.5^{dw}	307.4 ± 17.8^{dw}	40.3 ± 1.9^{dw}	81
Potato	CRI	*Solanum tuberosum cv. Granola*	yellow	Boiled	unknown	Y	nl=4, nw=3	2.93*	22.3^					1
Potato	COL	*Solanum tuberosum L.*	yellow	Raw	without		nl=4	1 ± 0.2	12 ± 1	4 ± 0.5				8
Potato	COL	*Solanum tuberosum L.*	yellow	Cooked	without		nl=4	1.5 ± 0.3	44 ± 1	21 ± 0.5				8
Potato	PAN	*Solanum tuberosum*	yellow	Raw		Y	nw=3		70 ± 10	50 ± 10				7
Potato, Andean	PER	*Solanum phureja (705821)*	light yellow	Raw	with	Y	nw=3	20 ± 2	81 ± 8	n.d		38 ± 5	25 ± 3	72
Potato, Andean	PER	*Solanum phureja (705821)*	light yellow	Boiled	with	Y	nw=3	26 ± 3	95 ± 19	<LD		11 ± 4	16 ± 4	72
Potato, Andean	PER	*Solanum phureja (705172)*	light yellow	Raw	with	Y	nw=3	27 ± 4	123 ± 11	<LD		57 ± 5	28 ± 2	72
Potato, Andean	PER	*Solanum phureja (705172)*	light yellow	Boiled	with	Y	nw=3	32 ± 3	155 ± 10	<LD		10 ± 4	12 ± 1	72
Potato, Andean	PER	*Solanum goniocalix (704393)*	intermediate yellow	Raw	with	Y	nw=3	7.4 ± 0.3	180 ± 10	17 ± 1		294 ± 19	168 ± 14	72
Potato, Andean	PER	*Solanum goniocalix (704393)*	intermediate yellow	Boiled	with	Y	nw=3	<LD	185 ± 14	41 ± 3		78 ± 10	71 ± 15	72
Potato, Andean	PER	*Solanum goniocalix (701862)*	intermediate yellow	Raw	with	Y	nw=3	12 ± 2	290 ± 22	<LD		432 ± 30	63 ± 8	72
Potato, Andean	PER	*Solanum goniocalix*	intermediate yellow	Boiled	with	Y	nw=3	9.2 ± 0.6	253 ± 5	21 ± 1		36 ± 7	<LD	72

		(701862)												
Potato, Andean	PER	*Solanum goniocalix (702472)*	deep yellow	Raw	with	Y	nw=3	7.3 ± 0.9	77 ± 5	562 ± 16		59 ± 5	172 ± 7	72
Potato, Andean	PER	*Solanum goniocalix (702472)*	deep yellow	Boiled	with	Y	nw=3	<LD	73 ± 6	555 ± 13		<LD	45 ± 4	72
Potato, Andean	PER	*Solanum phureja (705799)*	deep yellow	Raw	with	Y	nw=3	15 ± 2	105 ± 21	588 ± 32		72 ± 10	310 ± 17	72
Potato, Andean	PER	*Solanum phureja (705799)*	deep yellow	Boiled	with	Y	nw=3	10 ± 2	113 ± 23	571 ± 33		34 ± 7	163 ± 63	72
Potato, Andean	PER	*Solanum phureja (704218)*	deep yellow	Raw	with	Y	nw=3	<LD	96 ± 6	1048 ± 61		38 ± 8	190 ± 4	72
Potato, Andean	PER	*Solanum phureja (704218)*	deep yellow	Boiled	with	Y	nw=3	<LD	96 ± 8	1013 ± 55		<LD	<LD	72

[dw] - dry weight basis; * *E*-isomers; ^ includes zeaxanthin; LD - Limit of detection; VM - validated method; nl - number of lots; nw - number of replicates; Y – Yes; N - No; () – range

Table 16. Carotenoids in cereals and similar (µg/100 g)

Name	Origin (Country)	Scientific name	Colour	Process	SAP (Y/N)	QA	*α*-carotene	*β*-carotene	*β*-cryptoxanthin	lutein	zeaxanthin	Ref
Maize	CRI	*Zea mays cv. Diamantes*	Yellow	Boiled	Y	VM	1.94	14 11.7*	1.25	42^		1
Maize	BRA	*Zea mays* var. Assum preto	Yellow			nl=3		53 ± 7	91 ± 3	360 ± 12	401 ± 7	77
Maize	BRA	*Zea mays*. var. BR 473	Yellow			nl=3		28 ± 1	82 ± 5	148 ± 4	467 ± 25	77
Maize	BRA	*Zea mays* var. Asa branca	Yellow			nl=3		77 ± 2	140 ± 4	181 ± 7	565 ± 23	77
Maize	BRA	*Zea mays* Asteca	Yelow and orange	Milled	N	nw=26			4 ± 1	244 ± 15	390 ± 28	82
Maize	BRA	*Zea mays* Amarelao 3	Yellow	Milled	N	nw=26			1 ± 0.0	590 ± 3	118 ± 5	82
Maize	BRA	*Zea mays* Branco	White	Milled	N	nw=26			<LD	3 ± 3	7 ± 5	82
Maize	BRA	*Zea mays* Cateto	Yellow and	Milled	N	nw=26			2 ± 0	110 ± 11	188 ± 20	82

			red								
Maize	BRA	*Zea mays* CatetoVermelho	Yellow and red	Milled	N	nw=26		3 ± 0	125 ± 3	252 ± 3	82
Maize	BRA	*Zea mays* Composto São Luiz	Yellow	Milled	N	nw=26		4 ± 0	144 ± 12	203 ± 19	82
Maize	BRA	*Zea mays* Cunha 1	Yellow	Milled	N	nw=26		2 ± 1	480 ± 26	350 ± 52	82
Maize	BRA	*Zea mays* Lıngua de Papagaio	Yellow and purple	Milled	N	nw=26		4 ± 0	61 ± 59	443 ± 20	82
Maize	BRA	*Zea mays* Mato Grosso	Yellow	Milled	N	nw=26		5 ± 0	257 ± 5	237 ± 15	82
Maize	BRA	*Zea mays* Mato Grosso Palha Roxa	Yellow and purple	Milled	N	nw=26		3 ± 0	252 ± 6	397 ± 15	82
Maize	BRA	*Zea mays* Moroti	Yellow	Milled	N	nw=26		<LD	142 ± 19	7 ± 7	82
Maize	BRA	*Zea mays* MPA1	Yellow	Milled	N	nw=26		6 ± 1	369 ± 51	705 ± 67	82
Maize	BRA	*Zea mays* MPA2	Yellow	Milled	N	nw=26		5 ± 1	276 ± 34	597 ± 75	82
Maize	BRA	*Zea mays* MPA13	White	Milled	N	nw=26		<LD	6 ± 6	16 ± 8	82
Maize	BRA	*Zea mays* Palha Roxa 2	yellow and purple	Milled	N	nw=26		1 ± 0	63 ± 6	149 ± 16	82
Maize	BRA	*Zea mays* Palha Roxa 18	yellow and purple	Milled	N	nw=26		3 ± 1	84 ± 14	240 ± 38	23
Maize	BRA	*Zea mays* Pires	yellow	Milled	N	nw=26		5 ± 1	236 ± 4	418 ± 5	23
Maize	BRA	*Zea mays* Pixurum 1	orange	Milled	N	nw=26		4 ± 0	135 ± 5	300 ± 10	23
Maize	BRA	*Zea mays* Pixurum 4	yellow and orange	Milled	N	nw=26		5 ± 0	248 ± 10	149 ± 25	82
Maize	BRA	*Zea mays* Pixurum 5	yellow	Milled	N	nw=26		2 ± 1	65 ± 9	139 ± 13	82
Maize	BRA	*Zea mays* Pixurum 6	orange	Milled	N	nw=26		3 ± 1	130 ± 13	426 ± 36	82
Maize	BRA	*Zea mays* Pixurum 7	white	Milled	N	nw=26		<LD	4 ± 2	8 ± 2	82
Maize	BRA	*Zea mays* Rajado 8 Carreiras		Milled	N	nw=26		4 ± 0	10 ± 1	30 ± 3	82

Maize	BRA	*Zea mays* Rosado 38		Milled	N	nw=26			1 ± 0	35 ± 5	64 ± 7	82
Maize	BRA	*Zea mays* Roxo 29	purple	Milled	N	nw=26			2 ± 1	186 ± 5	482 ± 8	82
Maize	BRA	*Zea mays* Roxo 41	purple	Milled	N	nw=26			10 ± 1	85 ± 5	1070 ± 147	82
Maize	ESP	*Zea mays*	yellow	Raw	N	nw=3	<LD	<LD	<LD	411	218	21
Maize, boiled	PAN	*Zea mays*		Raw	Y	nw=4				280 ± 40	370 ± 50	7
Maize, flour	PAN	*Zea mays*		Raw	Y	nw=4				210 ± 20	940 ± 70	7
Tritordeum	ESP	*xTritordeum Ascherson et Graebner (HT1)*	yellow	Raw	N	nl=24				290 (130-590)		83
Tritordeum	ESP	*xTritordeum Ascherson et Graebner (HT2)*	yellow	Raw	N	nl=29				260 (90-480)		83
Tritordeum	ESP	*xTritordeum Ascherson et Graebner*		Flour	N	n=4		7.7 ± 0.005		544 ± 0.064* 68.8 ± 0.011**		84
Tritordeum	ESP	*xTritordeum Ascherson et Graebner HT1*		Flour	N					300^{f} 420^{me} 170^{de}		83
Tritordeum, 53 accessions	ESP	*xTritordeum Ascherson et Graebner HT7*		Flour	N					230^{f} 130^{me} 30^{de}		83
Tritordeum, 53 accessions	ESP	*xTritordeum Ascherson et Graebner HT27*		Flour	N					270^{f} 330^{me} 110^{de}		83
Tritordeum, 53 accessions	ESP	*xTritordeum Ascherson et Graebner HT51*		Flour	N					250^{f} 210^{me} 40^{de}		83
Tritordeum, 53 accessions	ESP	*xTritordeum Ascherson et Graebner HT55*		Flour	N					180^{f} 90^{me} 10^{de}		83

Tritordeum, 53 accessions	ESP	*xTritordeum Ascherson et Graebner HT71*	Flour	N	360^{f} 310^{me} 70^{de}	83
Tritordeum, 53 accessions	ESP	*xTritordeum Ascherson et Graebner HT75*	Flour	N	370^{f} 310^{me} 90^{de}	83
Tritordeum, 53 accessions	ESP	*xTritordeum Ascherson et Graebner HT79*	Flour	N	360^{f} 310^{me} 80^{de}	83
Tritordeum, 53 accessions	ESP	*xTritordeum Ascherson et Graebner HT80*	Flour	N	340^{f} 250^{me} 60^{de}	83
Tritordeum, 53 accessions	ESP	*xTritordeum Ascherson et Graebner HT84*	Flour	N	260^{f} 240^{me} 80^{de}	83
Tritordeum, 53 accessions	ESP	*xTritordeum Ascherson et Graebner HT86*	Flour	N	340^{f} 270^{me} 80^{de}	83
Tritordeum, 53 accessions	ESP	*xTritordeum Ascherson et Graebner HT89*	Flour	N	250^{f} 340^{me} 120^{de}	83
Tritordeum, 53 accessions	ESP	*xTritordeum Ascherson et Graebner HT91*	Flour	N	300^{f} 170^{me} 30^{de}	83
Tritordeum, 53 accessions	ESP	*xTritordeum Ascherson et Graebner HT96*	Flour	N	400^{f} 320^{me} 90^{de}	83
Tritordeum, 53 accessions	ESP	*xTritordeum Ascherson et Graebner HT114*	Flour	N	280^{f} 90^{me} 10^{de}	83
Tritordeum, 53 accessions	ESP	*xTritordeum Ascherson et Graebner HT127*	Flour	N	230^{f} 200^{me} 40^{de}	83

Tritordeum, 53 accessions	ESP	*xTritordeum Ascherson et Graebner HT131*	Flour	N	240[f] 230[me] 70[de]	83
Tritordeum, 53 accessions	ESP	*xTritordeum Ascherson et Graebner HT138*	Flour	N	130[f] 100[me] 30[de]	83
Tritordeum, 53 accessions	ESP	*xTritordeum Ascherson et Graebner HT164*	Flour	N	270[f] 200[me] 50[de]	83
Tritordeum, 53 accessions	ESP	*xTritordeum Ascherson et Graebner HT176*	Flour	N	140[f] 170[me] 170[de]	83
Tritordeum, 53 accessions	ESP	*xTritordeum Ascherson et Graebner HT195*	Flour	N	210[f] 130[me] 30[de]	83
Tritordeum, 53 accessions	ESP	*xTritordeum Ascherson et Graebner HT198*	Flour	N	400[f] 270[me] 40[de]	83
Tritordeum, 53 accessions	ESP	*xTritordeum Ascherson et Graebner HT223*	Flour	N	250[f] 230[me] 70[de]	83
Tritordeum, 53 accessions	ESP	*xTritordeum Ascherson et Graebner HT224*	Flour	N	590[f] 230[me] 30[de]	83
Tritordeum, 53 accessions	ESP	*xTritordeum Ascherson et Graebner HT2*	Flour	N	170[f] 210[me] 80[de]	83
Tritordeum, 53 accessions	ESP	*xTritordeum Ascherson et Graebner*	Flour	N	200[f] 380[me] 210[de]	83

		HT9				
Tritordeum, 53 accessions	ESP	*xTritordeum Ascherson et Graebner HT10*	Flour	N	350[f] 350[me] 80[de]	83
Tritordeum, 53 accessions	ESP	*xTritordeum Ascherson et Graebner HT13*	Flour	N	180[f] 230[me] 80[de]	83
Tritordeum, 53 accessions	ESP	*xTritordeum Ascherson et Graebner HT28*	Flour	N	230[f] 330[me] 170[de]	83
Tritordeum, 53 accessions	ESP	*xTritordeum Ascherson et Graebner HT31*	Flour	N	170[f] 300[me] 190[de]	83
Tritordeum, 53 accessions	ESP	*xTritordeum Ascherson et Graebner HT64*	Flour	N	270[f] 370[me] 150[de]	83
Tritordeum, 53 accessions	ESP	*xTritordeum Ascherson et Graebner HT110*	Flour	N	170[f] 280[me] 190[de]	83
Tritordeum, 53 accessions	ESP	*xTritordeum Ascherson et Graebner HT143*	Flour	N	300[f] 290[me] 80[de]	83
Tritordeum, 53 accessions	ESP	*xTritordeum Ascherson et Graebner*	Flour	N	480[f] 360[me] 100[de]	83

		HT148				
Tritordeum, 53 accessions	ESP	*xTritordeum Ascherson et Graebner HT150*	Flour	N	310[f] 320[me] 130[de]	83
Tritordeum, 53 accessions	ESP	*xTritordeum Ascherson et Graebner HT152*	Flour	N	360[f] 270[me] 80[de]	83
Tritordeum, 53 accessions	ESP	*xTritordeum Ascherson et Graebner HT157*	Flour	N	480[f] 310[me] 50[de]	83
Tritordeum, 53 accessions	ESP	*xTritordeum Ascherson et Graebner HT221*	Flour	N	290[f] 290[me] 70[de]	83
Tritordeum, 53 accessions	ESP	*xTritordeum Ascherson et Graebner HT240*	Flour	N	220[f] 250[me] 100[de]	83
Tritordeum, 53 accessions	ESP	*xTritordeum Ascherson et Graebner HT263*	Flour	N	400[f] 380[me] 110[de]	83
Tritordeum, 53 accessions	ESP	*xTritordeum Ascherson et Graebner HT265*	Flour	N	250[f] 330[me] 120[de]	83
Tritordeum, 53 accessions	ESP	*xTritordeum Ascherson et Graebner HT290*	Flour	N	140[f] 250[me] 160[de]	83

Tritordeum, 53 accessions	ESP	*xTritordeum Ascherson et Graebner HT292*	Flour	N	180[f] 260[me] 150[de]	83
Tritordeum, 53 accessions	ESP	*xTritordeum Ascherson et Graebner HT320*	Flour	N	190[f] 270[me] 100[de]	83
Tritordeum, 53 accessions	ESP	*xTritordeum Ascherson et Graebner HT323*	Flour	N	210[f] 280[me] 120[de]	83
Tritordeum, 53 accessions	ESP	*xTritordeum Ascherson et Graebner HT325*	Flour	N	90[f] 190[me] 160[de]	83
Tritordeum, 53 accessions	ESP	*xTritordeum Ascherson et Graebner HT327*	Flour	N	140[f] 160[me] 70[de]	83
Tritordeum, 53 accessions	ESP	*xTritordeum Ascherson et Graebner HT332*	Flour	N	220[f] 190[me] 40[de]	83
Tritordeum, 53 accessions	ESP	*xTritordeum Ascherson et Graebner HT333*	Flour	N	190[f] 280[me] 110[de]	83
Tritordeum, 53 accessions	ESP	*xTritordeum Ascherson et Graebner HT335*	Flour	N	230[f] 300[me] 130[de]	83
Tritordeum, 53 accessions	ESP	*xTritordeum Ascherson et Graebner*	Flour	N	280[f] 360[me] 170[de]	83

		HT609						
Tritordeum, 53 accessions	ESP	*xTritordeum Ascherson et Graebner HT630*		Flour	N		390^{f} 380^{me} 100^{de}	83
Tritordeum, 53 accessions	ESP	*xTritordeum Ascherson et Graebner HT632*		Flour	N		300^{f} 240^{me} 70^{de}	83
Wheat, Durum	ESP	*Triticum spp. Don Pedro*		Flour	N		120^{f} 30^{me} $<LD^{de}$	83
Wheat, Durum	ESP	*Triticum spp. Simeto*		Flour	N		70^{f} 20^{me} $<LD^{de}$	83
Wheat, Durum	ESP	*Triticum spp. T155*		Flour	N		140^{f} 40^{me} $<LD^{de}$	83
Wheat, Durum	ESP	*Triticum spp. T22*		Flour	N		60^{f} 10^{me} $<LD^{de}$	83
Wheat, Durum	ESP	*Triticum spp. T60*		Flour	N		80^{f} 20^{me} $<LD^{de}$	83
Wheat, Durum	ESP	*Triticum spp. Vitrón*		Flour	N		90^{f} 20^{me} $<LD^{de}$	83
Wheat, Durum	ESP	*Triticum sp durum DH2652*		Flour	N		100^{f} 20^{me} $<LD^{de}$	83
Wheat, durum	ESP	*Triticum spp.*	yellow	Raw	N	nl=7	90 (60-140)	83

^{f} - free; ^{me} - monoester; ^{de} – diester; * *E*-isomers; ** *Z*-isomers; ^ includes zeaxanthin; LD - Limit of detection; VM - validated method; nl - number of lots; nw - number of replicates; Y – Yes; N - No; () - range

Table 17. Carotenoids in miscellaneous (µg/100 g)

Name (english)	Origin (Country)	Scientific name	Colour	Process	SAP (Y/N)	QA	***α***-carotene	***β***-carotene	lycopene	lutein	zeaxanthin	phytofluene	*ζ*-carotene	latoxanthin	Ref
Black palm	PAN	*Astrocaryum standleyaum*		Raw	Y	nw=4				440 ± 30	<LD				7
Cashew	PAN	*Anacardium occidentale*		Raw	Y	nl=2, nw=5				30 (20 - 40)	10				7
Cow milk	BRA		white		Y	nl=2, nw=15		944* (807–1081)*		115 (97 - 132)	95 (83 - 106)			994 (807-1081)	85
Sofrito* **	ESP			Cooked	N	nl=10.,nw=4	80* (68-110)*	1876* (1330-2969)*	3088* (2932-4050)* 584** (518-678)**	288* (241-342)*					86
Tomato ketchup	BRA					nl=6		350 ± 0.8* 100 ± 0.3**	9425* (8560 - 10290)* 815** (630 - 1000)**			1205 (850 - 1560)	255 (150 - 360)		24

* *E*-isomers; ** *Z*-isomers; ***Sofrito-garlic. onion. paprika. tomato. olive oil; LD - Limit of detection; VM - validated method; nl - number of lots; nw - number of replicates; Y – Yes; N – No; () – range

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