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EFFECT OF COOKING AND INDUSTRIAL PROCESSING ON LEVELS AND BIOACCESSIBILITY/BIOAVAILABILITY OF CAROTENOIDS

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Introduction

Many fruit and vegetables are subjected to various types of processing prior to consumption, involving procedures such as washing, peeling, cutting, blanching, addition of processing chemicals, drying (dehydration), freezing and canning. Fruits are widely processed into jams, jellies and single- and mixed-fruit juices, where procedures such as pulping, juice extraction and pasteurization are employed prior to packaging. All these procedures have a potential impact on carotenoid content, bioaccessibility and bioavailability[1]. It is important to keep in mind that generalizations in this aspect need to be taken with a degree of caution as, depending on the food matrix and the type of process performed on it, the effects of processing on the content, bioaccessibility and bioavailability of carotenoids may be different. In addition, the same process on the same food matrix can have different effects on different carotenoids. Nowadays, both the food industry and researchers explore new processing and cooking techniques in order to reduce the loss of carotenoids or even to increase it and, at the same time, to improve their bioavailability.

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Bioaccessibility and bioavailability: The concept

Although there are discrepancies regarding the meaning of the terms bioaccessibility and bioavailability of carotenoids, the most accepted definitions are:

The bioaccessibility can be defined as the fraction of ingested carotenoids that is available for intestinal uptake or absorption when released into the gastrointestinal tract and incorporated into mixed micelles[2,3]. The bioaccessibility is usually expressed as the percentage of the carotenoid content that remains in the micellar aqueous fraction after centrifugation and filtration in an in vitro digestion assay in relation to the respective initial content in the original undigested matrix.

The bioavailability can be defined as the fraction of ingested carotenoids that is available for it utilization in physiological functions or for storage[4]. In many cases, to assess the total exposure of an organism to

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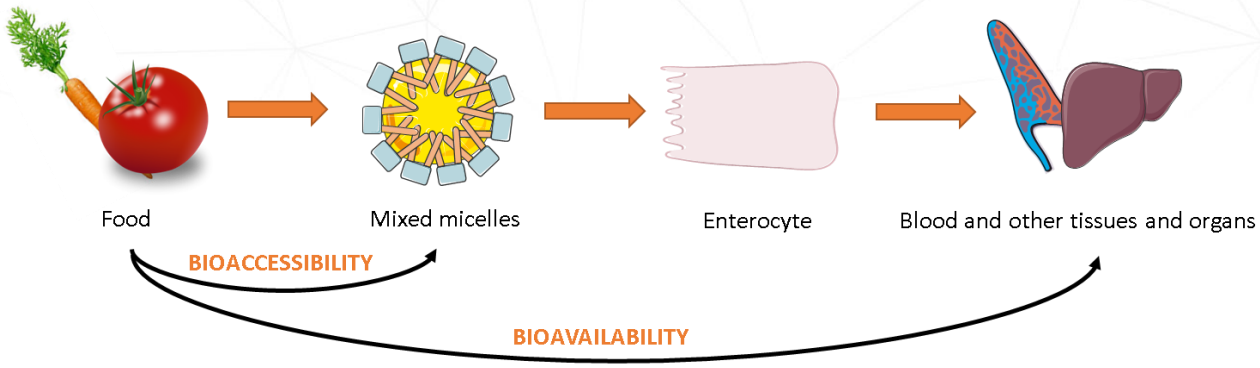

Figure 1. Graphic representation of the terms bioaccessibility and bioavailability.

carotenoids and study the bioavailability profile, the value of the area under the curve (AUC) is calculated. AUC is obtained by representing the concentration values of carotenoids in plasma, serum or chylomicrons as a function of time after the intake of products rich in these compounds.

Effects of cooking and industrial processing

As stated before, it is important to bear in mind that food treatments may have different effect on the level and bioaccessibility/bioavailability of carotenoids depending on the food matrix, the type of treatment and even the type of carotenoid. Thus, general statements about the effect of treatments should be used with caution.

In most cases, heat treatments applied in industrial processing, such as pasteurization and sterilization by steaming, boiling, roasting, or microwave among others or during cooking result in a decrease in carotenoid content and in an increase in their bioaccessibility/bioavailability[1,5–10]. The main reason for the loss of carotenoids is that these are thermolabile compounds, and so they are susceptible to degradation by the action of heat, especially under severe processing and storage conditions[11,12]. In addition, heat can favour breakage of cell structures which result in a greater exposure of carotenoids to the acidic environment and the enzymes present in many fruits and vegetables and to oxygen, which in turn may cause a decrease in the concentration of carotenoids. Other processes that generate a physical degradation of the food matrix, such as powdering or juicing could also have the same effect. In general, the greater the degradation of the food matrix, the greater the carotenoid losses[13,14]. However, some studies have found an increase in the concentration of carotenoids after some thermal industrial treatments or cooking. The authors of these studies indicate that this fact is due to the greater ease in the extraction of carotenoids from matrices in which, as a result of these treatments, the particle size is smaller[12]. On the other hand, the increase in the bioaccessibility/bioavailability as a consequence of some thermal treatments and cooking process is due mainly to the destruction of the natural barriers for release of carotenoids to the gastrointestinal fluids, i.e. the breakage of cell walls, intracellular organelles and protein-carotenoid associations in those matrices where they exist[15–18]. It is also noteworthy that thermal treatments can favour the attack of the digestive enzymes by increasing the surface area, which also contribute to increase the carotenoids bioaccessibility[19]. Moreover, these treatments induce isomerization of trans-isomers to cis-isomers, which in turn, increase the bioaccessibility/bioavailability as the latter isomer are more soluble in mixed micelles and better absorbed from the intestinal lumen due to the bend in their conformation[7,17,20,21].

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In addition to conventional heat treatments, a wide variety of novel food processing technologies, such as high pressure processing (HPP) and those that use pulsed electric fields (PEF), ultrasound (US) and microwave (MW), have emerged in the last decades. Although their effects on carotenoids have already begun to be studied more researches are needed on this important issue.

The total carotenoid content of fruits and vegetables is generally either unaffected or increased by preservation using HPP, which is a novel non-thermal technology that uses water as a medium to transmit pressures, usually up to 800 MPa[22,23]. As with thermal processing, the disruption of the cell walls promoted by HPP, which result in a greater ease in the carotenoid extraction from the matrices, could explain an increase in the carotenoid concentration after the treatment[22]. Regarding the carotenoid bioaccessibility, it is common to find an increase as a result of the application of HPP, also mainly due to this cellular breakage. However, some researchers have reported decreasing in the bioaccessibility due to the entrapping of carotenoids in fibre networks formed by microstructural changes in the matrices, making the carotenoids less accessible to the digestive enzymes and bile salts[19].

Analogous to HPP, US causes the disruption of the cellular structures, which enhance the carotenoids bioaccessibility; but it also promotes the formation of fibre networks and so decreases in the bioaccessibility have also been found[24].

On the other hand, PEF technology usually increase the carotenoid bioaccessibility by inducing cell membrane rupture and enhancing the enzymatic hydrolysis of carotenoid esters[19,24].

MW heating can be used as a pasteurization technique and seems to cause carotenoid degradation[22]. It has been observed that the bioaccessibility of lycopene increases by microwaving a tomato paste and that the bioaccessibility of the main carotenoids of a kiwi puree is not affected by the microwave[19].

Recently, the possibility of using UV radiation as an alternative to phytosanitary postharvest treatments is being evaluated and, although there are conflicting results, it seems that these treatments can increase carotenoid content[25].

During food processing and cooking it is common to add some type of oil. In this regard, it has been shown that, in general, the addition of oil increases the bioaccessibility of carotenoids, but the increase will depend on the type of fat, the matrix and the type of carotenoid[14,26,27].

Conclusions

Given that there is a wide variety of industrial treatments and cooking methods and that the type of matrix can influence the effect that a certain treatment has on carotenoids, it is difficult to obtain a general conclusion in this regard. Heat treatments are, among the most widely used treatments, the most extensively studied and, although there are researches with conflicting results, in general, it can be stated that they give rise to two opposite effects. On the one hand, they cause the degradation of carotenoids (negative effect) and, on the other hand, they generate an increase in their bioaccessibility and hence usually in their bioavailability (positive effect). For all the above, it can be inferred that more studies are needed on the effects of processing and cooking on carotenoids and that the study of the effect of novel treatments merit particular attention.

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