Abiotic stress combination to improve healthiness of fresh vegetables smoothies

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Abstract

Several epidemiological studies have revealed the potential benefits of an appropriate and equilibrated diet rich in fruit and vegetables to prevent several diseases in those people with genetic predisposition. Phytochemicals of vegetables, such as phenolic compounds, carotenoids and vitamins offer health-promoting benefits. Orange vegetables, such as carrots, pumpkin, sweet potatoes, etc., are very popular in the Mediterranean diet. These vegetables are important contributors of antioxidants in the diet as polyphenols, carotenoids and vitamins (A, C, E, etc). Accordingly, these vegetables could be used as a functional food if the content of such phytochemicals is enhanced. Abiotic stresses, such as UV-C, superatmospheric oxygen, wounding, etc., applied during postharvest can be used as a tool to enhance phytochemicals. Hence, these stressed vegetables with high health-promoting properties can be consumed as a functional food, with high added value, or as a natural nutraceutical to be included in other functional foods like beverages like smoothies.

Keywords: functional food; bioactives; plant biofactories; phenolics; carotenoids

1. State of the art

The current worldwide drive for a healthier lifestyle has led to a rising demand for convenient fresh foods, free from additives, with high nutritional value, including antioxidant and free-radical scavenging properties, to be consumed both in food services and at home [1]. Consumer demands in the field of food production have changed considerably in the last decades. Consumers more and more believe that foods contribute directly to their health. Today foods are not intended to only satisfy hunger and to provide necessary nutrients for humans but also to prevent nutrition-related diseases and improve physical and mental well-being of the consumer. In this regard, functional foods play an outstanding role. The increasing demand on such foods can be explained by the increasing cost of healthcare, the steady increase in life expectancy and the need to satisfy population groups with special needs such as elderly and children [2].

Carrot (*Daucus carota* L.) is a popular vegetable among children and adults. The popularity of this vegetable is mainly due to the pleasant flavour, bright orange colour, healthiness and relative cheapness among other properties. Carrot is the major vegetable source of provitamin A carotenoids (especially β-carotene) in the human diet, which have been reported to be protective against certain types of cancers and to have other health benefits [3].

Pumpkin (*Cucurbita* spp.) is one of the well-known edible plants and has substantial medicinal properties due to the presence of unique natural edible substances. It contains several phyto-constituents belonging to the categories of alkaloids, flavonoids, and palmitic, oleic and linoleic acids. Various important medicinal properties including anti-diabetic, antioxidant, anti-carcinogenic, anti-inflammatory and others have been well documented [4].

Sweet potato (*Ipomoea batatas* [L.] Lam) could be considered as an excellent novel source of natural health-promoting compounds, such as *β*-carotene and anthocyanins, for the functional food market. The high concentration of anthocyanin and β-carotene in sweet potato, combined with the high stability of the colour extract make it a promising and healthier

alternative to synthetic colouring agents in food systems [5].

Reactive oxygen species could be important cause active agents of a great number of human diseases. Antioxidant components provide protection against harmful free radicals, which are produced by aerobic metabolism and have been strongly associated with reduced risk of chronic diseases, such as cardiovascular diseases, cancer, diabetes, Alzheimer's disease, cataracts and age-related functional decline, in addition to other health benefits. Diets rich in orange and dark-green have been associated with a reduction in chronic diseases such as cardiovascular diseases, certain cancers and type 2 diabetes. These protective effects are generally credited to the additive and synergistic effect of antioxidants and other nutrients found in these vegetables. The importance of consuming orange and dark-green vegetables is underscored by the Healthy People 2010 guidelines, which include an objective to increase the proportion of individuals aged 2 years and older who eat at least one daily serving. The '5 A Day' is a worldwide campaign (Spain, USA, United Kingdom, Germany, Canada, etc.) to encourage the consumption of at least five portions of fruit and vegetables each day, following a recommendation by the World Health Organization that individuals consume 'a minimum of 400g of fruit and vegetables per day (excluding potatoes and other starchy tubers)' [6]. The US Department of Agriculture also included a specific recommendation for dark-green and orange vegetable intake in the 2005 Dietary Guidelines for Americans. In general, 0.6 to 0.9 servings of dark-green vegetables and 0.4 to 0.6 servings of orange vegetables per week are recommended for adults. Yet, recent research indicates that intakes of dark-green and orange vegetables among Americans do not meet recommendations [7].

Numerous studies have demonstrated that the lung and others types of cancer are inversely related with the consumption of carotenes [8]. Phenolic compounds in fruits and vegetables are of great interest in two respects. First, they contribute to the sensory qualities of fruits and vegetables: colour, astringency, bitterness, and aroma. Second, some phenolics possess pharmacological properties and are used for therapeutic purposes [9]. The accumulation of phenolic compounds represents a major key factor in the inducible defence mechanisms of plants through the phenylpropanoid pathway. The induction of the phenylpropanoid metabolism could be also achieved experimentally by treatments with elicitors or exposure to specific stress conditions. However, wound signalling in plants is a complex process involving a whole array of molecules with regulatory activity, where the linear signalling pathways can form networks allowing overlapping and interlinking of signals or cross-talk [10].

The fresh-cut produce market has undergone a rapid growth within the food industry, caused by trends in life style, diet, importance for health, and healthy alternative in restaurants. Additionally, there is an increasingly growing market for nutraceuticals and functional foods. Enhancing the health benefit properties of fruits and vegetables will add value and create new opportunities for growers and processors by reaching health-oriented markets. However, minimal processing operations damage fruits and vegetables tissue integrity which triggers deteriorative processes including oxidative browning, tissue softening, water loss and development of undesirable flavours and odours. In addition, removal of the natural protective epidermal barrier and increase of the moisture and dissolved sugars contents on the product surface provide ideal conditions for microbial colonization and proliferation [11,12]. Accordingly, there is a need to provide technologies that can ensure the delivery of high quality products, safe and with high levels of the desired nutraceuticals [1].

The application of postharvest abiotic stresses in fresh fruits and vegetables induces the accumulation of antioxidants. Among different fruits and vegetables, carrots have shown an excellent response to abiotic stresses to increase their health-promoting compounds [13,14,15]. Carrots respond to wounding stress accumulating phenolic compounds such as caffeoylquinic and ferulic acids. These antioxidant compounds are highly absorbed and metabolized in humans [13]. As a postharvest treatment, UV-C irradiation has proven beneficial to reduce respiration rates, to rot development control, and to delay senescence and ripening in different fruit and vegetables. Packaging under high oxygen conditions can be used to decrease microbial growth during shelf life of fresh-cut fruits and vegetables. Furthermore, this technique may keep sensory attributes, reducing enzymatic browning and preventing anaerobic fermentation and moisture and odour losses. The antimicrobial effect of high oxygen atmospheres, contrary to

the high CO_2 levels reached within packages throughout storage, is not well known yet [12,16]. The most important enzymes associated with discoloration and browning are peroxidase and polyphenol oxidase. In addition, surface-tissue lignification of fresh-cut carrots leads to unfavourable colour changes that reduce acceptability. It has been observed that wounding activates the natural tissue defence mechanisms such as increased phenylalanine ammonia lyase activity, the key enzyme of the phenylpropanoid pathway [14].

To increase the intake of fruits and vegetables, as an alternative and/or addition to the consumption of fresh fruits and vegetables, the food industry offers the manufacture of beverages such as juices and smoothies. Smoothies, originally consisting of purely fresh fruits and vegetables, were first introduced in the 1960 in United States and re-emerged in the 2000. Smoothies are blended drinks consisting of a number of ingredients including fruit (or less commonly vegetables), fruit juice, ice, yoghurt and milk. There are three main types of smoothies: fruit only, fruit and dairy, and functional. Smoothies could contribute to the supply of fruits and vegetables, especially to people who cannot consume fresh fruits and vegetables mainly due to market availability and/or convenience. Depending on the manufacture and composition, one smoothie could be enough to replace the nutritional value of at least one portion of fruits or vegetables [17].

The objective of this PhD Thesis will be to develop smoothies of orange vegetables with high content of bioactive compounds. The bioactive content of harvested vegetables will be conducted through abiotic stresses. Accordingly, conditions of abiotic stresses will be optimized in order to obtain the maximum bioactive content enhancements in the vegetables which will be used to obtain functional smoothies. Furthermore, optimum thermal and non-thermal treatments will be studied in order to obtain a product with excellent sensory attributes during its commercial life meeting always the applicable food safety regulations.

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