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Bioactive components in F&V

Edito

Plant dietary products are rich in numerous vital micronutrients- vitamins and minerals- and bioactive compounds, such as carotenoids and polyphenols. Their consumption, associated to a better lifestyle, contributes to the well-being and prevention of chronic diseases.

In this series, a focus is done by Prof. Shashirekha on polyphenols, which are particularly abundant in fruits and vegetables. Dietary polyphenols display a large range of compounds with diverse biological activities contributing, certainly altogether, to the health benefits ascribed to a higher consumption of fruits and vegetables. Interestingly, Vinha and her collaborators reported that polyphenols are submitted to moderate losses during cooking of green vegetables, whereas vitamin C is reduced by about 50% and could reach more than 70% in thin leafy vegetables. Because the retention of polyphenols is higher than vitamin C and carotenoids, it could explain the health benefits of Mediterranean-type diets, composed of diverse boiled vegetables. Recommendations for better food practices to avoid micronutrient losses are essential in South Asia, where food insecurity and child malnutrition are prevalent.
Prof. Srinivasan points towards the importance to promote strategies to improve the bioavailability of micronutrients, either by eliminating some plant dietary compounds, such as phytates or oxalates which hinder the absorption of iron, zinc and calcium, or by incorporating ingredients enhancing bioavailability. These findings highlight the impact of food processing and the role of meal complexity on health effects.

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Bioactive components in fruit and vegetables: The case of polyphenols

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Fruit and vegetables (FV) have a spectacular range of health effects which can be attributed to the numerous compounds such as vitamins, minerals, fibers, phytosterols, saponins, glucosinates and polyphenols that they contain. For the polyphenols, despite their beneficial effects on human health, especially for their antioxidant and chemo-preventive properties, no recommended daily intake has been established. This could be mainly explained by the current lack of knowledge on their biological activities, the inconclusive data on bioavailability and pharmacokinetics and the incomplete food composition data in regard to the numerous dietary phenolic structures.

As polyphenols are largely distributed in fruit and vegetables in derived products such as flavonoids, phenolic acids, stilbenes and lignans, this could be another valuable assertion for strengthening the positive image of these foods and recommendation for consumption.

The difficulty for quantifying the food composition of polyphenols

The International Network of Food Data Systems (INFOODS) has already created a programme to acquire and interchange food composition databases around the world. In conjunction with the work on the usual macro- and micronutrients, it would be relevant to improve the quality and availability of bioactive compounds data such as that on polyphenols. It could also be interesting to match up such information with the dietary patterns of each country, in order to improve the health status of vulnerable populations. For example, the health status of obese Mexican rural populations could be improved by the consumption of local fruits and vegetables-an important source of polyphenols with antioxidant properties and dietary fibre[1].

The assessment of dietary intake of polyphenols has already been done in some countries. Brazilians and US adults have a high dietary intake of polyphenols especially flavonoids, with an estimation of 60-106 mg/day and 190 mg/day respectively. In Brazil this would be mainly attributed to the consumption of fruits and vegetables, with 70% coming from oranges, 8.9% from lettuce, and 5.8% from onions. These figures seem high when compared to the dietary intake in Finland (55mg/day) or Denmark (29 mg/day).

Polyphenols content and antioxidant activity in F&V

In the last few years, several bioactive compounds such as polyphenols have been reported in food composition databases. It appears that fruit and vegetables are the major source of polyphenols with levels such as black grapes (91.2 mg/100g), apples (56.3 mg/100g), guavas (126.4/100g), strawberries (97.6 mg/100g), broccoli sprouts (73.8 mg/100g) or artichoke (260.3 mg/100g).

Moreover it was found that the stage of ripening (immature, mature, ripe, and over-ripe) in fruit, such as Durian, may influence the amount of polyphenols and the antioxidant activities with higher levels being identified in over-ripe fruits[2].

Antioxidant activity has been found to be proportionate to the content of flavonoids. For example, in the litchi fruit, a positive correlation was demonstrated between its antioxidant property and flavonoid content (28.8mg/100g). As well, proanthocyanidin tannins of the Feijoa fruit were responsible for its antioxidant activity[3].

Biological activities and health benefits

The high antioxidant activity of polyphenols can prevent lipid peroxidation and DNA protein damage. In fact many dietary polyphenols are antioxidants capable of quenching ROS (reactive oxygen species) and toxic free radicals formed by the peroxidation of lipids and thus have anti-inflammatory and antioxidant properties in human metabolism. Moreover, when specific foods are combined – such as fruits (raspberry, blackberry, and apple), vegetables (broccoli, tomato, mushroom, and purple cauliflower), and legumes (soybean, adzuki bean, red kidney bean, and black bean) a synergistic antioxidant interaction could occur resulting in a more positive physiological effect on cardio-health[4]. Moreover diets supplemented with tropical fruit rich in polyphenols, such as Durian (309.7mg/100g) or mangosteen (190.3 mg/100g) could hinder the rise in plasma lipids and decrease in antioxidant activity.

Although some clinical observations using polyphenols showed positive outcomes for human health[5], further research needs to be conducted to assess their bioavailability and thus their biological effects.

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The cooking effect on the phytochemical content of green vegetables traditionally consumed in the Mediterranean diet

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Health benefits of green vegetables in the Mediterranean diet

The Mediterranean diet was recognized by UNESCO as an Intangible Cultural Heritage, being characterized by a nutritional model that has remained constant over time and includes a large variety of vegetables. The consumption of green vegetables has, undoubtedly, a positive effect in health promotion, reducing the risk of cardiovascular diseases, cancer, cataract and macular degeneration, obesity and Type 2 diabetes, among others[1]. Inevitably, all these effects are related to the amounts of bioactive compounds of each type of vegetable, but such compounds are often heat sensitive and can be degraded during cooking processes. In fact, cooking aims to increase the digestibility and palatability of vegetables, apart from improving food safety by avoiding potential pathogens and reducing the intake of some anti-nutrients such as tannins. Taking into consideration the lack of information about boiling effects on the contents of vitamin C, carotenoids and phenolic compounds of green vegetables traditionally consumed in the Mediterranean diet, this study developed a comprehensive evaluation about this topic in 11 selected green vegetables.

Determination of the bioactive compounds in boiled vegetables

Boiling was performed by adding each vegetable sample to boiling tap water (~100 ºC) in a covered stainless-steel pot (1:5 vegetable-water) for exactly 10 minutes. This period was selected as the minimum cooking time needed for adequate sample palatability and taste. Aqueous extracts (~5 g/ 100 mL) of raw and cooked vegetables were obtained by stirring at 25 ºC, for 1 h, and used to determined vitamin C[2] and total phenolics[3]. For the determination of total carotenoids content a different extraction was used, according to the method proposed by Wang and Liu[4]. Statistical analysis was performed using SPSS v. 21 (IBM Corp., Armonk, NY, USA). Data of all analysis, in triplicate, are expressed as mean ± standard deviation. After validating the assumptions of multivariate normality and homogeneity of variance-covariance, a MANOVA analysis was used to compare the results from different vegetables.

Cooking can strongly influence the content of bioactive compounds

Cooking induces some chemical and physical modifications in foods, including the phytochemical content. The contents of the analyzed bioactive compounds are presented in Table 1.

According to the results, some of the raw vegetables are excellent sources of bioactive compounds. Vitamin C contents were quite variable, ranging from 10.6 mg (lettuce) to 255 mg/ 100 g (collard). The variability in carotenoids content was even larger: cauliflower presented only traces (0.03 mg/ 100g) while spinach showed a 100-fold higher value. Phenolic compounds were the most representative phytochemicals in all vegetables. Cooking can drastically influence the content of all the bioactive compounds analyzed. Overall the major loss was observed for vitamin C, with a 77.7% decrease in spinach. The carotenoid degradation reached 40%, in particular to lettuce, savoy cabbage and broccoli. The smaller losses were obtained for total phenolic contents, with a loss of 30% in lettuce and 20% in broccoli, whereas watercress, spinach, savoy cabbage and broccoli rape leaves had similar content between raw and boiled products. ($p > 0.05$).

Considering their losses in bioactive compounds, the most affected vegetables were broccoli rape leaves and buds, broccoli and lettuce, and the least affected ones were collard and tronchuda cabbage. This could be explained by the relatively thick epicuticular waxy layer on collard and tronchuda cabbage leaves which may provide an additional barrier, reducing the mass and heat transfer, and the leaching of the compounds during boiling.

In Mediterranean gastronomy, as vegetables are often boiled to become more edible, these results may be useful for consumers' food practices.

Table1. Bioactive compounds (mg/100 g) of 11 types of raw and boiled vegetables[a]

	Raw			Boiled		
Vegetables	**Vitamin C**	**Carotenoids**	**Phenolics**	**Vitamin C**	**Carotenoids**	**Phenolics**
Broccoli	**49.6±1.0[h]**	**1.11±0.01[f]**	**455.9±1.6[h]**	**22.2±1.1[i]**	**0.69±0.1[g]**	**369.1±1.7[i]**
Broccoli rape buds	**100.8±1.6[d,e]**	**1.09±0.01[f]**	**554.3±0.8[f]**	**41.0±2.2[f]**	**0.78±1.6[f]**	**482.0±2.9[g]**
Broccoli rape leaves	**115.0±7.9[b,c]**	**1.21±0.01[e]**	**403.6±1.6[i]**	**46.0±5.3[d]**	**0.84±3.9[e]**	**399.5±0.9[h]**
Cabbage	**90.8±3.4[e,f]**	**0.41±0.01[i]**	**561.8±0.9[e]**	**31.0±1.7[h]**	**0.29±2.1[j]**	**524.0±2.6[e]**
Cauliflower	**69.1±1.7[g]**	**0.03±0.01[j]**	**202.9±0.6[k]**	**45.4±1.8[e]**	**0.02±0.02[k]**	**174.7±1.1[k]**
Collard	**255.1±9.7[a]**	**2.50±0.07[b]**	**747.8±0.6[c]**	**144.8±4.5[a]**	**2.09±1.6[b]**	**720.5±1.1[c]**
Tronchuda cabbage	**105.8±8.0[d,c]**	**1.39±0.01[d]**	**608.9±0.9[d]**	**58.8±1.9[c]**	**1.24±1.2[d]**	**589.5±2.2[d]**
Lettuce	**10.6±0.9[i]**	**0.80±0.01[h]**	**393.0±1.5[j]**	**4.88±1.0[k]**	**0.48±0.9[i]**	**274.2±3.6[j]**
Savoy cabbage	**70.7±1.4[g]**	**0.97±0.01[g]**	**816.8±0.8[b]**	**40.1±1.2[g]**	**0.61±0.04[h]**	**809.6±0.7[b]**
Spinach	**40.8±1.6[h]**	**3.29±0.05[a]**	**1010.7±1.1[a]**	**9.1±1.2[j]**	**2.94±0.1[a]**	**1003.0±1.3[a]**
Watercress	**122.3±1.6[b]**	**1.98±0.02[c]**	**502.7±1.4[g]**	**77.9±2.7[b]**	**1.40±0.2[c]**	**506.4±2.9[f]**

a Values expressed as mean ± standard deviation obtained from 3 measurements per replicate. Within each column, different superscript letters represent significant differences between samples ($p<0.05$).

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Derive maximum nutritional benefits from plant foods

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In India the prevalence of iron and vitamin A deficiencies is widespread. Almost 79% of children between 6 and 35 months and women between 15 and 49 years are anemic and 60 % of preschool children are suffering from sub-clinical deficiencies of vitamin A. In addition to their low dietary intakes, this could be also explained by the lowest bioavailability of minerals of plant-based foods as well as the culinary practices, which can reduce the vitamin and mineral contents.

All the nutrients we consume through our diets are not fully available to the body for absorption, depending on other components present in the meal. However, there are ways to overcome this problem by judiciously selecting food combinations and processing them wisely.

Loss of nutrients during food processing

Although domestic food processing improves the taste, the flavour and the palatability of food, food practices could result in a considerable loss of nutrients, particularly vitamins and minerals. For example, processing of grains by dehusking, milling, polishing and pre-cooking processes, leads to a partial loss of nutrients. Moreover, heat sensitive vitamins (vitamin B1, C) are more susceptible to degradation during heat processing but these losses can also occur by the leaching of water-soluble vitamins into the cooking water (vitamin B1, B9, B12), and by the destruction of unstable vitamins due to oxidation (ß-carotene, vitamins C and E).

Nutrient Bioavailability

The bioavailability of proteins, iron, zinc, calcium and the pro-vitaminic ß-carotene is influenced by several components, which can reduce or increase their absorption:

- Lectins, present in legumes, by direct binding, inhibit the activity of the protein hydrolyzing enzymes. Therefore, the presence of lectins leads to the incomplete digestion of proteins and lowers their bioavailability. However, legume cooking inactivates these protease inhibitors and hence improves the bioavailability of dietary proteins.
- Organic acids present in food acidulants such as lime or amchur, enhance the absorption of non-heme iron from plant foods (from 30 to 86%) by reducing ferric iron to ferrous iron. These acids also increase the intestinal absorption of dietary zinc from 11 to 44%.

  Ascorbic acid present in fruit and vegetables is the most potent promoter of trace metal absorption. Thus, consumption of citrus fruit after a meal should help in the absorption of trace minerals, while drinking tea or coffee rich in polyphenols immediately after a meal, will be disadvantageous.
- Phytates and dietary fibre present in cereals and millets, and oxalates present in some green leafy vegetables, are chelators of cations, such as calcium, iron and zinc, and hinder their absorption.

The right food combination for a better nutrition

Even if some nutrients are lost during food processing, cooking of plant food generally improves the bioavailability of nutrients. Heat treatment of green leafy and yellow-orange vegetables by pressure-cooking, stir-frying and open-pan boiling, lead to an increase of the bioaccessibility (in vitro) of ß-carotene from 21 to 84%, 67 to 191%, and 23 to 36%, respectively.

Sprouting and malting of grains generally enhances iron absorption due to elevated vitamin-C content and reduced tannin or phytate content. These processes activate endogenous phytases, which in turn hydrolyse phytates, rendering iron and zinc more available. Fermentation of grains also improves mineral bioavailability by reducing phytate content.

Plant food matrix influences ß-carotene absorption, as mild cooking releases this carotenoid from the food matrix and facilitates its bioavailability. Furthermore, ß-carotene from the yellow-orange fruits such as mango and papaya can be absorbed to a greater extent, from 12 to 56% and 19% to 38% respectively, if these fruits are consumed as a blend along with milk.

Recently new enhancers of micronutrient bioaccessibility were identified. Common to Indian culinary ingredients, they include sulphur compound-rich Allium spices (onion and garlic), ß-carotene-rich vegetables (amaranth), and pungent spices (pepper and ginger). Awareness of their beneficial influence would help in devising dietary strategies to improve the bioavailability of essential nutrients.