Effects of domestic cooking process on the chemical and biological properties of dietary phytochemicals

Chao Zhao, Yuanyuan Liu, Shanshan Lai, Hui Cao, Yi Guan, Wai San Cheang, Bin Liu, Kewei Zhao, Song Miao, Céline Riviere, Esra Capanoglu, Jianbo Xiao

PII: S0924-2244(17)30776-8

DOI: https://doi.org/10.1016/j.tifs.2019.01.004

Reference: TIFS 2390

To appear in: *Trends in Food Science & Technology*

Received Date: 10 December 2017

Revised Date: 23 July 2018

Accepted Date: 4 January 2019

Please cite this article as: Zhao, C., Liu, Y., Lai, S., Cao, H., Guan, Y., San Cheang, W., Liu, B., Zhao, K., Miao, S., Riviere, C., Capanoglu, E., Xiao, J., Effects of domestic cooking process on the chemical and biological properties of dietary phytochemicals, *Trends in Food Science & Technology*, https://doi.org/10.1016/j.tifs.2019.01.004.

Abstract

Foods are good sources of vitamins, minerals and dietary fibers as well as phytochemicals, which are beneficial for the human body as nutritional supplements. The nutritional value (crude fibers, crude proteins, crude fats, flavonols, carotenoids, polyphenols, glucosinolate, chlorophyll, and ascorbic acid) and nutritional properties (antioxidant activity, anticancer activity, or antimutagenic activity) of foods can be well retained and protected with the appropriate cooking methods. The chemical, physical and enzyme modifications that occur during cooking will alter the dietary phytochemical antioxidant capacity and digestibility. This paper reviewed the recent advances on the effects of domestic cooking process on the chemical and biological properties of dietary phytochemicals. Furthermore, the possible mechanisms underlying these changes were discussed, and additional implications and future research goals were suggested. The domestic cooking process for improving the palatability of foods and increasing the bioavailability of nutrients and bioactive phytochemicals has been well supported.

Effects of domestic cooking process on the chemical and biological properties of dietary phytochemicals

Chao Zhao[1,3#], Yuanyuan Liu[1#], Shanshan Lai[1], Hui Cao[1,2]*, Yi Guan[4], Wai San Cheang[2], Bin Liu[1], Kewei Zhao[5], Song Miao[6], Céline Riviere[7], Esra Capanoglu[8], Jianbo Xiao[2]*

[1]College of Food Science, Fujian Agriculture and Forestry University, Fuzhou 350002, China

[2]Institute of Chinese Medical Sciences, State Key Laboratory of Quality Research in Chinese Medicine, University of Macau, Macau

[3]Fujian Province Key Laboratory for the Development of Bioactive Material from Marine Algae, Quanzhou Normal University, Quanzhou 362000, China

[4]College of Biological Science and Engineering, Fuzhou University, Fuzhou 350116, China

[5]Research Division, US Department of Veterans Administration, North Hills, CA 92343, USA

[6]Food Chemistry and Technology Department, Teagasc Food Research Centre, Moorepark, Fermoy, Co.Cork, Ireland

[7]Agro-food and biotechnology research Institute Charles Viollette, Faculty of Pharmacy, University of Lille (Lille 2), 3 rue du Professeur Laguesse, BP 83 F-59006 LILLE Cedex, France

[8]Department of Food Engineering, Faculty of Chemical and Metallurgical Engineering, Istanbul Technical University, Maslak, Istanbul TR-34469, Turkey

[#]These authors contributed equally to this work.

*To whom correspondence should be addressed: Dr. Hui Cao, State Key Laboratory of Quality Research in Chinese Medicine, University of Macau, Macau, E-mail: hui_cao0830@yahoo.com

Prof. Dr. Jianbo Xiao, Institute of Chinese Medical Sciences, State Key Laboratory of Quality Research in Chinese Medicine, University of Macau, Macau, E-mail: jianboxiao@yahoo.com

Abstract: Foods are good sources of vitamins, minerals and dietary fibers as well as phytochemicals, which are beneficial for the human body as nutritional supplements. The nutritional value (crude fibers, crude proteins, crude fats, flavonols, carotenoids, polyphenols, glucosinolate, chlorophyll, and ascorbic acid) and biological or functional properties (antioxidant activity, anticancer activity, or anti-mutagenic activity) of foods can be well retained and protected with the appropriate cooking methods. The chemical, physical and enzyme modifications that occur during cooking will alter the dietary phytochemical antioxidant capacity and digestibility. This paper reviewed the recent advances on the effects of domestic cooking process on the chemical and biological properties of dietary phytochemicals. Furthermore, the possible mechanisms underlying these changes were discussed, and additional implications and future research goals were suggested. The domestic cooking process for improving the palatability of foods and increasing the bioavailability of nutrients and bioactive phytochemicals has been well supported.

Keywords: Domestic cooking; Phytochemicals; Chemical profiles; Biological properties

1. Introduction

Food processing has been carried out since ancient time as a way to preserve and improve the nutritional and organoleptic properties of foods. However, it can also result with some undesired consequences such as the losses of nutrients and the formation of toxic compounds with negative effects on flavor, texture, or color (Friedman, 2015; Mogol & Gokmen, 2016; Zamora, León, & Hidalgo, 2015). On the other hand, the benefits of food processing cannot be ignored including the improvement of food safety, enhancement of nutritional value, and formation or release of natural phytochemicals with functional and bioactive properties (*i.e.*, antioxidant or antimicrobial properties) (Nayak, Liu, &Tang, 2015; Van Boeckel et al., 2010). For instance, the formation of pyropheophytins is frequently found after the heating of green plant tissues (Schwartz & Elbe, 2010). Cooking induced the formation of pyropheophytin *a* (Chen & Roca, 2018). The increase in dietary fibre after domestic cooking may be because of the formation of complexes between polysaccharides and proteins in the food or resistant starch in cooked potatoes (Dhingra, Michael, Rajput, & Patil, 2012). Different cultures and countries have different cooking processes. Steaming, boiling and frying shape the eating habits of Western societies, while stir-frying gets used to prepare most homemade dishes in China (Ruiz-Rodriguez, Marín, Ocańa, & Soler-Rivas, 2008). Food quality often depends on the influences of primary production and industrial processing. Different food cooking methods at home as the final step have great influence on natural phytochemical profiles and biological properties. It can change them either in a positive or negative way (Bernhardt & Schlich, 2006).

Vegetables are excellent sources of carbohydrates, minerals, vitamins (specifically, ascorbic acid (***1***), β-carotene (provitamin A, ***2***)), dietary fiber, and other bioactive phytochemicals (Fig. 1) (Dolkar et al., 2017; Kosinska-Cagnazzo et al., 2017; Michalska et al., 2017; Pan et al., 2017; Sarkar et al., 2017; Prodanov, Sierra, & Vidal-Valverde, 2004; Rao and Rao, 2007). Phytochemicals are plant bioactive compounds mainly found in fresh vegetables, marine algae and fruits, which are broadly classified as phenolics, carotenoids (*i.e.* β-carotene (***2***), α-carotene (***3***), lutein (***4***), and zeaxanthin (***5***), alkaloids, and nitrogen-containing/organosulfur compounds (Chen et al., 2017a and 2017b; Luo et al., 2017; Neves and Caldas, 2017; Pinela, Carvalho, & Ferreira, 2017, Teng et al., 2017; Wu et al., 2017; Xiao, 2017). Numerous studies have been focused on the effect of cooking methods on dietary phytochemicals (Gliszczynska-Swiglo et al., 2006; Miglio, Chiavaro, Visconti, Fogliano, & Pellegrini, 2008; Zhao et al., 2018). The cooking conditions are clearly evident in inducing a series of changes in the physical properties, chemical composition and enzyme modifications of foods (Rothwell et al., 2015). However, such findings on the changes in the phytochemical and biological properties that various vegetables undergo during domestic cooking were inconsistent and sometimes contradictory. For instance, Blessington and coworkers (2010) reported that total phenolic content and antioxidant activity are significantly increased during boiling, baking, frying and microwaving in potatoes. In contrast, Xu, Li, Lu, Beta, & Hydamaka (2009) concluded that boiling, baking and microwaving decreased the phytochemical concentrations and their antioxidant activities. Faller & Fialho (2009) reported a significant increase in the total phenolic content of potatoes during boiling, as well as microwaving. However, the antioxidant activity of potatoes decreased significantly during boiling according to Burgos et al. (2013).

Foods can provide polyphenols such as flavonoids (Costa et al., 2017; Faller & Fialho, 2009; Karas, Ulrichova, & Valentova, 2017; Lin & Chang, 2005), anthocyanins (***6***) (Monero, Perez-Balibrea, Ferreres, Gil-Izquierdo, & García-Viguera, 2010), powerful glucosinates (***7***) resveratrol (Mallebrera et al., 2017; Orellana-Palma et al., 2017; Santhakumar et al., 2017) and isothiocyanates. These major biologically active compounds were entrusted to exhibit high anti-carcinogenic and antioxidant activities *in vitro* and *in vivo* (Verkerk et al., 2009) and played an important role in the prevention of many chronic diseases (Williams et al., 2013). Absorption and disposition of natural phytochemicals after food processing in humans have been widely studied. Vegetables and their associated phytochemicals appear to increase antioxidant capacities and concomitantly suppress oxidative stress and inflammation (Fig. 2). And the effect of dietary phytochemicals was closely associated with combating free radicals and reducing the oxidative damage which are responsible of causing chronic diseases (Tiwari & Cummins, 2013). Even so, they are also too fragmented to have a good view of the effect of cooking methods on the nutritional quality of foods. Many studies have usually investigated one vegetable species with limited cooking methods. In this review, we aim to provide an overview of food processing on the content and biological activities of natural dietary phytochemicals.

2. Different domestic cooking techniques and their effects on food composition

Foods are cooked using different ways according to the traditional recipes and culinary shills of various countries for home consumption. The heat cooking methods include a wide variety of processes, *i.e.*, boiling, steaming, frying, baking and roasting, and use of microwave ovens (Palermo, Pellegrini, & Fogliano, 2014). These thermal processes can improve the sensory and textural features of the food material. Moreover, natural phytochemicals such as polyphenols, glucosinolates (*7*) and carotenoids will be released by the disruption of cell walls, breakdown of complex molecular structures, and dissociation of molecular linkages between food components (Hidalgo & Zamora, 2017). In addition, thermal processes also produce new bioactive compounds by the Maillard and carbonyl-amine reactions (Henle, 2005). Microwave heating treatment has been widely employed to inactivate enzymes in vegetable products (Redondo, Venturini, Oria, & Arias, 2016). These different domestic cooking techniques promote a better accessibility and availability of many food components, such as natural antioxidants, and also the rate of Maillard reaction and lipid oxidation (Santos et al., 2015; Wong, Chai & Xiao, 2018). To report the changes that occur during food processing, major dietary phytochemicals and biological properties were selected. The influence of different cooking methods on natural phytochemical profiles and biological properties of foods were all summarized in Table1, Table 2, and Table 3.

Various chemical and physical changes may occur during cooking, and especially the proximate composition of the food is altered. The effect of different cooking methods on proximate composition was shown in the Table 1. The cooking methods may greatly affect the content of food nutrients, for example, frying seems to have a great influence on the nutritional quality. Numerous biochemical reactions take place in the hot medium and several new chemical compounds are produced. The crude fat content is significantly increased during frying (increases of 4.07 ± 0.15 g/100 g dry weight) as the cooking oil is absorbed during this process (Tian, Chen, Ye, & Chen, 2016; Tian et al., 2016). The cooking oils are obtained from oilseeds (*i.e.* mustard, sunflower, and cottonseed), food legumes (*i.e.* soybean and peanut), nuts (*i.e.* almond,) or fruit pulp (*i.e.* olives) (Kumar, Kumeshini, & Xu, 2017). The hydrolysis of cooking oil is observed at the beginning of cooking, in which the acid value of the oil is enhanced due to the production of free fatty acids from triglycerides (Kumar, Kumeshini, & Xu, 2017).

Besides the changes in the fat content, other components of the foods are also known to be affected. According to Murniece et al. (2011), the highest fibre content in the fried samples increased significantly to 1.93 ± 0.06 g/100 g fresh weight and was higher than that of the uncooked sample. It was reported that the cells were exposed to a high extent of structural damage, which brought out a loss of liposoluble chemical constituents in vegetables and caused an increase in the fibre content (Sun, Mu, Xi, & Song, 2014). On the other hand, the content of ash was decreased appreciably after frying. This is probably due to some pretreatments applied on the vegetables (*i.e.*, soaking in water) (Bethke & Jansky, 2008).

Cooking of vegetables can affect their bioactive compounds, which may cause beneficial or harmful effects. Foods with high-carbohydrates/low-protein compositions produce a large amount of acrylamide (***8***) when exposed to high temperatures through the Maillard reaction (Mottram, Wedzicha, & Dodson, 2002). Acrylamide (***8***) is a hydrophilic substance that has been considered as a probable human carcinogen (Daniali, Jinap, Hajeb, Sanny, & Tan, 2016). High amounts of acrylamide in foods result in an estimated daily mean intake of 50 μg for a western style diet. The average daily intake of acrylamide for adults in western countries was estimated to be in the range of 0.2 to 1.4 μg/kg body weight (Fuhr et al., 2006). It is necessary to reduce the acrylamide content to acceptable levels. The generated acrylamide (***8***) concentration depends on factors such as cooking time, temperature, and the amount of reducing sugars and free asparagine (Cheong, Hwang, & Hyong, 2005). There have been many measures to reduce acrylamide formation by the optimization of processing conditions. Current study revealed antioxidants play an important role in acrylamide formation. For this reason, the use of phenol additives for reducing acrylamide levels has been widely reported (Pérez-Nevado, Cabrera-Bañegil, Repilado, Martillanes, & Martín-Vertedor, 2018). Flavonoids exert their reduction effects on the formation of acrylamide in a nonlinear and bell-shaped dose-effect way. The mechanism by which flavonoids reduce the production of acrylamide can be attributed to their antioxidant properties by preventing lipid oxidation and the accumulation of carbonyls (Zhang, Huang, Wang, & Cheng, 2016). The addition of a flavonoid-rich spice mix could effectively reduce acrylamide levels by up to 50% in potato chips (Cheng, Chen, Zhao, & Zhang, 2015). It was also reported that the lowest concentration of acrylamide (***8***) was detected by submerging the potatoes in green tea flavonoid-rich extract containing water before frying (Morales, Jimenez, Garcia, Mendoza, & Beristain, 2014). Besides, asparaginase is considered as a potential agent in reducing the formation of acrylamide (Xu, Orunaconcha, & Elmore, 2016). Nachi et al. (2018) also demonstrated that fermentation processes performed with lactic acid bacteria and yeast could reduce the acrylamide content in bread. More interestingly, acrylamide (***8***) was not produced when it was heated in the absence of lipid other than the cooking oil (Daniali, Jinap, Hajeb, Sanny, & Tan, 2016).

3. Effects of cooking process methods on the dietary phytochemicals composition

3.1 Phenolic compounds

Phenolic compounds are known to be affected by food processing, and specifically by thermal treatments. As shown in Table 2, the total phenolic content was decreased after boiling, steaming, microwaving, baking, and frying (Ezekiel, Singh, Sharma, & Kaur, 2013; Tian, Chen, Ye, & Chen, 2016; Tian et al., 2016). This decrease may be due to water-soluble phenols leaching into the cooking water and the structural changes of phenolics that occurs during heat processing (Kita, Bąkowska-Barczak, Hamouz, Kułakowska, & Lisińska, 2013). Furthermore, the phenolic compounds participate in the interplay of the Maillard reaction, which results in an increase in the level of Maillard reaction products and decrease of phenolic level (Perla, Holm, & Jayanty, 2012). Steaming and microwaving are considered as the suitable methods for retaining the high level of phenolic compounds . Samples are not in contact with water and the inactivation of oxidative enzymes has prevented the disruption of phenolic biosynthesis and degradation during these cooking methods (Vallejo, Tomás-Barberán, & Garcia-Viguera, 2003).

Most researchers concluded that thermal treatments could lead to the reduction of phenolic content (Gonçalves, Pinheiro, Abreu, Brandão, & Silva, 2010; Zhang & Hamauzu, 2004). In contrast, several studies have revealed that the total phenolic contents in cooked potatoes were increased. Faller & Fialho (2009) reported that the content of phenolic compounds increased by 81.4%, 22.8%, and 80.81% after boiling, steaming and microwaving, respectively. In another study, as compared for before and after the treatment, baking, frying and microwaving treatments resulted with an increase by 36.36%, 46.12%, and 47.48% in the phenolic contents, respectively (Blessington et al., 2010). The increase may be attributed to the thermal action which induces the breakdown of vegetables structure, and as a result improves the extractability of phenolic compounds from the cellular matrix and stimulates the release of dietary fiber-bound polyphenols forming the free phenolic compounds (Ruiz-Rodriguez, Marín, Ocańa, & Soler-Rivas, 2008). During extrusion, the reduction of total phenolic contents with increasing temperature may be due to the decarboxylation of phenolic acids in fruit leather and the high moisture content of the feed, which could promote the polymerization of phenols and reduce extractability and antioxidant activity (Dlamini, Taylor, & Rooney, 2007). Furthermore, the heat treatments could inactivate polyphenol oxidases and prevent the oxidation and polymerization of polyphenols (Navarre, Shakya, Holden, & Kumar, 2010). In general, steaming and microwaving methods with lower temperatures and shorter times may be better for the retention of total phenolic contents (Tian, Chen, Ye, & Chen, 2016; Tian et al., 2016).

3.1.1. Phenolic acids

Phenolic acids play significant roles in human nutrition and health due to their antioxidant, anti-inflammatory, and anticarcinogenic effects (Balasundram, Sundram, & Samman, 2006). The phenolic acids include hydroxybenzoic and hydroxycinnamic acid derivatives. Hydroxybenzoic acids have a C6–C1 structure and include *p*-hydroxybenzoic (***9***), protocatechuic (***10***), gallic (***11***), vanillic (***12***) and syringic (***13***) acids (Singh, Singh, Kaur, & Singh, 2017). *p*-Hydroxybenzoic (***9***), protocatechuic (***10***), and vanillic (***12***) acids vary in beans, peas and lentils. Gallic acid (***11***) is the common phenolic acids found in beans.

Hydroxycinnamic acids are aromatic compounds having a C6-C3 structure and include caffeic (***14***), *p*-coumaric (***15***), *trans*-ferulic (***16***), sinapic (***17***) and chlorogenic (***18***) acids. Hydroxycinnamics vary in legumes such as beans, peas and lentils. *Trans*-ferulic acid is detected in beans, peas and lentils and *cis*-ferulic acid only in beans. *Trans*-*p*-coumaric acid is detected in lentils and peas, and *cis*-*p*-coumaric acid only in peas (Singh, Singh, Kaur, & Singh, 2017). Content and bioavailability of phenolic acids could be altered during processing. Cooking did not greatly affect the total phenolic acids of barley pasta, more leading to conserving free and bound phenolic compounds (De Paula, Rabalski, Messia, Abdel-Aal, & Marconi, 2017). However, phenolic substances in raw black rice cannot be obtained during boiling because its thermal degradation (Tang, Cai, & Xu, 2016). Phenolics in broccoli were lost heavily during conventional and microwave cooking, while the extent of loss would be lower in other processes, such as blanching and stir frying (Zhang & Hamauzu, 2004). The effect of cooking on phenolic acids profile and antioxidant properties of durum wheat pasta enriched with debranning fractions of wheat were studied by Fares, Platani, Baiano, & Menga. 2010. Surprisingly, pasta enhanced its antioxidant properties measured *in vitro* after cooking. The increase of antioxidant level depended on the increased amount of ferulic acid released during cooking. The boiling water could have enhanced the extraction of bound phenolics from the food matrix, primarily ferulic acid ester linked to cell walls (Fares, Platani, Baiano, & Menga. 2010).

3.1.2. Flavonoids

The cooking processes, such as boiling and extrusion, resulted in a significant reduction in flavonols (*i.e.* Quercetin (***19***) and Kaempferol (***20***)) in foods (Table 2). According to Giallourou, Oruna-Concha, & Harbourne (2016), all flavonols in watercress samples are lost in boiling water bath after 10 min. The decrease in total flavonoid content is caused by the destruction of flavonoids while treated with high temperatures (Sharma, Ramchiary, Samyor, & Das, 2016). Extrusion can decrease the total flavonoid content by the effect of heat and screw speed (Sharma, Ramchiary, Samyor, & Das, 2016). Flavonoids share a basic structure of diphenylpropanes (C_6-C_3-C_6) parent depending on the oxidation level of the central pyran ring. Due to an increase in the temperature and shear, the structural rings start to degrade and thus flavonoid content in the product is decreased. The increase in screw speed can result with an increase in the medium temperature, and thus the product temperature. Therefore, the combined effect of screw speed and temperature ultimately led to the loss of flavonoids (Sharma, Ramchiary, Samyor, & Das, 2016). On the other hand, the highest loss of flavonoids was observed during frying/microwaving (Barakat & Rohn, 2014). Frying and/or microwaving were the most dramatic treatments which cause the leaching of flavonoids into the frying oil, and then a following thermal degradation (Moreno, Lopez-Berenguer, & Garcia-Viguera, 2007; Vallejo, Tomás-Barberán, & Garcia-Viguera, 2003). Interestingly, according to some researchers, total flavonoids increased significantly in the range of 9.5% to 410.9% by the boiling processes because of an increased level of free flavonols (Singh et al., 2015).

Anthocyanins (***6***) are one of the most important classes of flavonoids and they are known to be highly unstable and easily affected by environmental factors, such as temperature, pH, oxygen, and light (Tian, Chen, Ye, & Chen, 2016; Tian et al., 2016). After frying, steaming, boiling, microwaving and baking, total anthocyanin content was significantly decreased (Brown, Durst, Wrolstad, & De, 2008; Table 2). Since anthocyanins (***6***) are highly water-soluble pigments, pretreatments such as soaking or blanching will also lead to the leaching of anthocyanins (***6***) into water during domestic and commercial processing (Tian, Chen, Ye, & Chen, 2016; Tian et al., 2016). Their greatest losses were caused by frying, air-frying and stir-frying with 57.06%, 44.53%, and 83.15%, respectively. Despite several studies reporting loss of anthocyanins as a result of processing, some contradictory results have also been reported. For example, increase in the concentration of total anthocyanins in cooked colored-flesh potatoes was observed after cooking treatments (Brown, Durst, Wrolstad, & De, 2008; Lachman et al., 2012; Lemos, Aliyu, & Hungerford, 2012). This increase was explained by three approaches; the first one indicates that anthocyanins (***6***) are enzymatically degraded in the presence of polyphenol oxidase, however, when heat treatments are applied, polyphenol oxidases are inactivated leading to the retention of anthocyanins (***6***). On the other hand, the second one points out that cooking treatments will destroy the microstructure of foods and induce a better extraction of anthocyanins (***6***) (Lemos, Aliyu, & Hungerford, 2012). Finally, the release of anthocyanins are susceptible to the type of cellular matrix and the kind of anthocyanins present in food (Brat, Tourniaire, &

Amiot-Carlin, 2008; Murador, Cunha, & Rosso, 2014). The cooking process involves changes to the structural integrity of the cellular matrix, softening the vegetable tissues and, consequently, increasing anthocyanins extraction and concentration (Chaovanalikit & Wrolstad, 2004; Murador, Cunha, & Rosso, 2014).

3.2 Carotenoids

The carotenoid content of foods was significantly affected by domestic cooking processes (Table 2). Carotenoids were reduced by all cooking methods in purple-fleshed potatoes, particularly frying, air-frying and stir-frying (Tian, Chen, Ye, & Chen, 2016; Tian et al., 2016). These treatments reduced the total carotenoid content from 66.30% to 76.16%. The loss of carotenoids is due to leaching into the oil and the degradation that occurs during thermal processing (Miglio, Chiavaro, Visconti, Fogliano, & Pellegrini, 2008). Mazzeo et al. (2011) identified that the carotenoids in freeze-dried carrot were β-carotene (***2***), α-carotene (***3***), lutein (***4***), phytofluene, and phytoene. The influence of cooking processes on β-carotene (***2***) and lutein (***4***) was slightly different. For β-carotene (***2***), steaming and microwaving were better methods followed by high pressure cooking. Whereas for lutein (***4***), pressure cooking was the best method followed by steaming and microwaving (Bureau et al., 2015). Mazzeo et al. (2011) have reported that β-carotene (***2***) was more susceptible to heat damage than α-carotene (***3***) during boiling, however, phytoene and phytofluene were considered to be increased. Less carotenes have been reported to be present in steamed carrot, but similar phytoene and phytofluene concentrations were observed with respect to the uncooked samples. Lutein (***4***) was only little affected by cooking processes. This behaviour was similar to the previous reports on fresh carrot and frozen Brussels sprouts (Pellegrini et al., 2010). The decrease may be due to their liposolubility and thermal sensitivity when treated with heat and oil.

On the other hand, according to some other researchers, domestic cooking may increase the carotenoids in comparison with the fresh-uncooked samples (Table 2). Higher carotenoid values have been reported for *Brassica* vegetables such as broccoli, Brussels sprouts, cabbage and cauliflower upon boiling and steaming (Bernhardt & Schlich, 2006; Gliszczynska-Swiglo et al., 2006). This phenomenon can be explained by the breakdown of cellulose in the plant cell wall, as well as improved extractability of carotenoids from carotenoid-containing plant material as a result of the denaturation of carotenoid-protein complexes during thermal processing (De Sa & Rodriguez-Amaya, 2003). Similarly, Burmeister et al. (2011) derived the same conclusion that carotenoids bonded with proteins in potatoes (*e.g.*, protein-xanthophyll aggregates) have been dissociated with a detectible increase in the carotenoids of cooked potatoes. According to their results, carotenoids were not adversely affected by heat treatments in some selected vegetables.

3.5 Ascorbic acid

Wide differences may occur in the ascorbic acid (***1***) content of foods because of variations in variety, cultivar, genetics, maturity stage, fertilization and environmental growing conditions on field. The ascorbic acid (***1***) concentration was reduced by processing conditions and cooking methods in vegetables (Table 2). The highest decrease was observed after boiling owing to its great water solubility (Bureau et al., 2015). However, Lachman et al. (2013) found that the highest decrease was observed in baked non-peeled cut potatoes, while the lowest was in boiled peeled ones. Its content decreased in average of all cultivars to 69% (boiling) of the original value of the raw non-peeled tubers. However, steaming and microwave heating did not cause any significant loss of ascorbic acid (***1***) compared with the fresh control (Bureau et al., 2015; Chuah et al., 2008; Xu et al., 2014). Thermal treatments can accelerate oxidation of ascorbic acid (***1***) to dehydroascorbic acid, followed by the hydrolysis to 2,3-diketogulonic acid and eventually polymerization to other nutritionally inactive components (Chuah et al., 2008). A decrease was observed in the ascorbic acid content in green and red peppers after stir-frying on account of high temperatures, long cooking times and enzymatic oxidation during preparation and cooking processes and frequent stirring that expose the materials to atmospheric oxidation (Somsub, Kongkachuichai, Sungpuag, & Charoensiri, 2008).

3.6 Glucosinolates

Glucosinolates (***7***) are a group of sulfur rich and important cancer chemo-preventive anionic secondary metabolites found principally in Brassicaceae vegetables (Wu et al., 2017). Stir-frying and boiling led to the highest loss of total glucosinolates (***7***), while microwaving and steaming had a subtle effect on glucosinolate (***7***) concentrations (Table 2). The decrease in the amount of glucosinolates (***7***) is caused by a range of stresses during postharvest handlings of vegetables (Jia et al., 2009). Cutting could let myrosinase get in contact with glucosinolates (*7*) before cooking, which lead to the hydrolysis of glucosinolates (*7*) more easily. Blanching also could lead to the depletion of water-soluble glucosinolates (*7*) in vegetables (Gliszczyńska-Swiglo et al., 2006). The modification in the enzyme activity promoted the breakdown processes (Jones, 2007; Palermo, Pellegrini, & Fogliano, 2014). The loss of total glucosinolates during boiling will be enhanced with increased cooking time and water volume (Dekke, Verkerk, & Jongen, 2000; Jones, 2007). However, microwaving and steaming showed no significant difference and a minor loss of glucosinolate (*7*) levels (Table 2), which is most likely due to denaturation and subsequent deactivation of the glucosinolate-degrading enzyme myrosinase, and depletes the hydrolysis of glucosinolates (*7*) to isothiocyanates. However, differently, an increase in the total glucosinolate (*7*) content was observed in red cabbage subjected to microwave (Verkerk & Dekker, 2004). Increase in other glucosinolates (*7*) in cooked *Brassica* vegetables by steaming was also reported (Pellegrini et al., 2010; Vallejo, Tomás-Barberán, & Garcia-Viguera., 2002). These inconsistent results regarding the effect of microwave and steaming on total glucosinolates (*7*) were probably as a result of different cultivars used and the time and power of the treatment (Xu et al., 2014). In addition, the environment in cells or cell compounds of the various cultivars and plant parts can exert a significant influence on the losses ranged from 6.6% to 77% and thermal stability of glucosinolates (Kapusta-Duch, Kusznierewicz, Leszczyńska, & Borczak, 2016; Song & Thornalley, 2007). Song & Thornalley (2007) demonstrated a progressive decrease in total glucosinolates content after boiling for 30 min of 58% in Brussels sprouts, 65% in green cabbage, 75% in cauliflower, and 77% in broccoli. Furthermore, the content of glucosinolates depends the plant cultivars, growing condition, climate, and the tissue-specific distribution in the plant parts.

3.7 Chlorophyll

Effect of cooking methods on chlorophylls (***21*** and ***22***) was investigated (Table 2). The content of chlorophylls in broccoli was increased after boiling, steaming, microwaving and sous vide, in which boiling is the most appropriate cooking method for broccoli inflorescences (Reis et al., 2015). The rate was 207% higher after boiling than in the fresh vegetable. However, green vegetables exhibit poor color quality and the chlorophyll content reduces after thermal processing (Adebooye, Vijayalakshmi, & Singh, 2008). Microwaving and frying treatments caused a significant loss of chlorophyll *a* (***21***) and chlorophyll *b* (***22***). On the other hand, they remained almost unchanged with steaming and baking methods (Barakat & Rohn, 2014). Chlorophylls *a* (***21***) and *b* (***22***) were also analyzed both in fresh broccoli inflorescences and after cooking (high pressure alone or high pressure and temperature). For chlorophyll *a*, high-pressure treatment caused no significant difference relative to the fresh vegetable. However, for chlorophyll *b*, high pressure at 70℃ yielded higher amounts of chlorophyll *b* than that measured for fresh inflorescences (Sánchez, Baranda, & Marañón, 2014). For chlorophyll *a* (***21***), boiling for 2 min produced higher concentrations than steaming, pressure and water, or pressure and steaming processes, even higher than that measured for fresh broccoli. For chlorophyll *b* (***22***) and total chlorophylls, raw material showed higher concentrations.

4. Effect of cooking process on biological properties of dietary phytochemicals

4.1 Antioxidant activity

Fruits are rich in important phytochemicals, such as ascorbic acid (***1***), mineral elements, flavonoids, carotenoids, and other compounds. These phytochemicals have a variety of biological properties including antioxidant, anti-inflammation, anti-mutagenicity, anti-carcinogenicity, and anti-aging activities (Ke, Pan, Xu, Nie, & Zhou, 2015; Rajendran et al., 2014), among which, antioxidant activity is a foundation of anti-cancer, anti-inflammation and anti-aging properties (Cai, Luo, Sun, & Corke, 2004; Ke, Pan, Xu, Nie, & Zhou, 2015). Effects of different cooking methods on antioxidant activities are shown in Table 3. The antioxidant activity was measured by DPPH (1,1-diphenyl-2-picryl-hydrazyl), ABTS (3-ethylbenzothiazoline-6-sulfonic acid) or FRAP (Ferric reducing antioxidant power) methods. DPPH is a free radical that has an unpaired valence electron on one atom of the nitrogen bridge, while ABTS is another free radical. Both of them have been considered as a tool for estimating free radical scavenging activities of antioxidants (Krishnaiah, Sarbatly, & Nithyanandam, 2010). The FRAP method was developed by Benzie & Strain (1996) which is also widely used in the measurement of antioxidant activity. The antioxidant activities of different phytochemicals are closely related to their chemical structures.

Antioxidants play a critical role in preventing many chronic diseases (Poljsak & Milisav, 2014), and the antioxidant capacity is associated with the phytochemicals (*i.e.*, phenolic, carotenoid, and anthocyanin) in fruits and vegetables (Tian, Chen, Ye, & Chen, 2016; Tian et al., 2016). The antioxidant responses and cellular adjustments are depicted in Fig. 3 (Embuscado, 2015; Espinosa-Diez et al., 2015; Rajendran et al., 2014). Mitochondria and NADPH oxidases (NOXs) are the two main sources of producing reactive oxygen species (ROS) (Lambeth, 2004). Mitochondrion releases either superoxide (O_2^-) or H□O□ and NADPH oxidases can generate O□ in the cytosol. The NF-κB interacts with the inhibitory κ-B (Iκ-B) proteins, which is phosphorylated by the IκB kinase (IKK) complex, leads to the ubiquitination and proteasomal degradation of the Iκ-B protein. NF-κB is released after stimulation and then can enter the nucleus and contribute to both survival and innate immune functions (Rius et al., 2008). Activation of IKK also occurs by phosphorylation and is catalyzed by an IKK kinase (Espinosa-Diez et al., 2015). The Nrf2-Keap1 pathway is the main regulator of cytoprotective responses to oxidative and electrophilic stress (Motohashi & Yamamoto, 2004), The Nrf2 protein is kept inactive by Keap1. During redox imbalance, ROS disrupt the Keap1-Nrf2 association (Kim, Cha, & Surh, 2010). Nrf2 can dissociate from Keap1 and enter the nucleus to combine with small Maf proteins and bind to the antioxidant response element, which is leading to activate the expression of a battery of cytoprotective genes. Ascorbic acid (***1***) has a direct role in scavenging reactive oxygen species (ROS), which can effectively scavenge a variety species of ROS and give off semi dehydroascorbic acid, clearing $^1O_2$ and reducing sulfur radicals (Amitava & Kimberly, 2014). Flavonoids can counteract lipid oxidation *in vitro* and improve the body’s antioxidant enzyme activity, and decrease peroxide formation *in vivo* (Nakao et al., 2011). Carotenoids have antioxidant activities through quenching $^1O_2$ and eliminating harmful free radicals. They can also ensure communication signals between cells and receptors on the cell membrane to maintain normal cell function and enhance human immunity by protecting immune cell membrane lipids from oxidative damage. Phytochemicals are influenced by cooking methods, and as a result the antioxidant activity is also affected during cooking procedures (Ezekiel, Singh, Sharma, & Kaur, 2013; Lemos, Aliyu, & Hungerford, 2015). Some studies reported that the antioxidant activity was related with the presence of phenolic constituents because of their abilities to scavenge free radicals (Ravichandran, Ahmed, Knnor, & Smetanska, 2012).

The antioxidant activity modestly reduced after boiling, and the decrease might be due to the leaching of antioxidant compounds into the cooking water (Giallourou, Oruna-Concha, & Harbourne, 2016; Girgin & Nehir, 2015). Whereas Burgos et al. (2013) found that the antioxidant activity has been increased by 10.67% in boiled purple-fleshed potatoes compared with the raw tuber. A decrease in anthocyanin (***6***) and polyphenol levels of purple potatoes after frying, but potato crisps still showed increased antioxidant activity (Kita, Bąkowska-Barczak, Hamouz, Kułakowska, & Lisińska, 2013). The reasons why the antioxidant activity was increased could be various. Two hypotheses have been proposed to explain this phenomenon. Firstly, heating may induce numerous chemical reactions, such as Maillard reaction, caramelization, Strecker degradation and hydrolysis of esters and glycosides which result in the production of new antioxidants (Kita, Bąkowska-Barczak, Hamouz, Kułakowska, & Lisińska, 2013). Maillard reaction occurs between an amino group and a sugar moiety, and can result with the formation of new substances which have been associated with increased antioxidant activity (Manzocco, Calligaris, Mastrocola, Nicoli, & Lerici, 2001). Secondly, the increased antioxidant activity on baked samples can be attributed to the heat leading to the denaturation of the endogenous enzymes, degrading the antioxidants (Kamiloglu et al., 2014). Generally speaking, the changes in the antioxidant activity during cooking arise from the changes in phytochemicals according to most of the studies.

4.2 Protective activity against cancer

In recent years, researchers have been attracted with the health effects of dietary polyphenols which contain at least one aromatic ring bearing one or more hydroxyl groups whose antioxidant action is mainly due to their high tendency to chelate metals by the referred groups. Their potent antioxidant properties are associated with inhibition of diseases, such as cancer. They can also modulate the activity of a wide range of enzymes and cell receptors. Therefore, polyphenols have been considered to have anticancer properties. The plant-derived food extracts with identified phenolic antioxidants showed anti-proliferative activities in different cancer cell lines (Fernanda et al., 2015). Since evidences suggesting that the higher intake of saturated fat can increase the incidence of cancer, obesity is frequently associated with many types of cancer (Kushi et al., 2012). It can be concluded that a healthier diet composed of higher intake of fruits and vegetables, and lower intake of red and processed meat, could be protective against colorectal adenoma and cancer incidence. The lower levels of some carotenoids in the blood may link to the higher risk of breast cancer, suggesting that consuming colored plant foods could prevent breast cancer (Kabat et al., 2009). Another study reported that the higher intake of isoflavones which are abundant in soybeans can lower the risk of endocrine-related gynecological cancers (Myung, Ju, Choi, & Kim, 2009). Consuming more vegetables, fruits and other foods rich in phenolic antioxidants may reduce the risk of some types of cancer.

Evidence from epidemiological studies showed that diets rich in fruits and vegetables show a lower incidence of human cancers. Fruits and vegetables contain inhibitors of carcinogenesis including potent antimutagens such as flavonoids and coumarins. Curcumin is a kind of well-known dietary polyphenol which has also been shown to be a potent inhibitor of several environmental mutagens requiring metabolic activation (Shishu & Kaur, 2008). Some previous studies have shown that the antimutagenic activity is affected by cooking methods. The antimutagenic activity was reduced using high pressure processing as well as steaming and boiling in cauliflowers and tomatoes (Girgin & Sedef, 2015).

4.3 Anti-inflammatory activity

Phytochemicals have received much attention due to their many health benefits, including anti-inflammatory activity. The anti-inflammatory potential of cooked navy and black bean was assessed in C57BL/6 mice model (Zhang et al., 2014b). The bean-fed mice showed a reduction in the expression of colonic inflammatory cytokines IL-6, IL-9, IFN-γ and IL-17A and an augmentation in the anti-inflammatory cytokine IL-10, which suggest that it might have the potential to improve health. Cooked chickpeas from Desi variety had high anti-inflammatory activities. Phenolic compounds were the most potent anti-inflammatory compounds in cooked chickpeas protein digests and inhibited much more effectively and dose-dependently the production of NO in LPS-challenged macrophages (Milán-Noris, Gutiérrez-Uribe, Santacruz, Serna-Saldívar, & Martínez-Villaluenga, 2018). Besides, sea cucumbers contain many bioactive compounds with potential health benefits. The anti-inflammatory properties of sea cucumber (*Isostichopus badionotus*) extracts were evaluated after being processed by cooking in water for 1 h at 100 °C followed by lyophilizing, or oven-drying at 70 °C for 12 h. Cooked and lyophilised, or oven-dried sea cucumber meals all exert anti-inflammatory effects on a mouse ear induced skin inflammation model (Olivera-Castillo et al., 2018).

5. Conclusions

The application of domestic cooking methods (boiling, frying, steaming, baking, microwaving, and extrusion) of fruits and vegetables can affect the nutritional values and functional properties of foods at different degrees. Although thermal processing partially results in the degradation of intrinsic phytochemicals and the denaturation of endogenous antioxidants, the nutritional dietary phytochemicals and their biological properties are well retained and protected with the appropriate cooking methods. In particular, numerous studies have been devoted to the effects of domestic cooking methods on phytochemicals and antioxidant activities. However, the effect of structural changes with the release of nutrients and phytochemicals during cooking was mostly ignored. As the changes in bioactive compounds can be beneficial or detrimental depending on the processing conditions, an assessment of their various physiological effects is necessary to be determined whether they should be preserved or eliminated. Meanwhile, the gentlest cooking methods for preserving the nutrients should still be investigated in future studies. Furthermore, even though both oriental and western people are accustomed to include flavorings, in most of the previous studies the effect of these flavorings, such as salt or vinegar was not considered. Since cooking is an essential part of our daily life, the mechanism of action by which various cooking processes exert their effects on phytochemicals which are related with human health merits further investigations in long-term operation. Based on profound research interest in food processing with dietary phytochemicals, the above directions in the future could be pursued.

Acknowledgements

This work was financially supported by Natural Science Foundation (2016J06009) of Fujian Province (China), Multi-Year Research Grant of University of Macau (MYRG2018-00169-ICMS), and Key Project of Fuzhou Municipal Bureau of Science and Technology (2018-G-87). The project was also supported by Fujian Province Key Laboratory for the Development of Bioactive Material from Marine Algae grant (2017FZSK05) and

FAFU grant KXb16011A.

References

Adebooye, O. C., Vijayalakshmi, R., & Singh, V. (2008). Peroxidase activity, chlorophylls and antioxidant profile of two leaf vegetables (*Solanum nigrum* L. and *Amaranthus cruentus* L.) under six pretreatment methods before cooking. *International Journal of Food Science and Technology, 43,* 173–178.

Ai, Y. F., Cichy, K. A., Harte, J. B., Kelly, J. D., & Perry K. W. N. (2016). Effects of extrusion cooking on the chemical composition and functional properties of dry common bean powders. *Food Chemistry*, *211*, 538–545.

Amitava, D., & Kimberly, K. (2014). Antioxidant vitamins and minerals. *Antioxidants in Food Vitamins and Supplements*, 277–294.

Balasundram, N., Sundram, K., & Samman, S. (2006). Phenolic compounds in plants and agri-industrial by-products: Antioxidant activity, occurrence, and potential uses. *Food Chemistry*, *99*(1), 191–203.

Barakat, H., & Rohn, S. (2014). Effect of different cooking methods on bioactive compounds in vegetarian, broccoli-based bars. *Journal of Functional Foods*, *11*, 407–416.

Benzie, I. F. F., & Strain, J. J. (1996). The ferric reducing ability of plasma (FRAP) as a measure of ‘‘antioxidant power”: The FRAP assay. *Analytical Biochemistry*, *239*(1), 70–76.

Bernhardt, S., & Schlich, E. (2006). Impact of different cooking methods on food quality: Retention of lipophilic vitamins in fresh and frozen vegetables. *Journal of Food Engineering*, *77*, 327–333.

Bethke, P. C., & Jansky, S. H. (2008). The effects of boiling and leaching on the content of potassium and other minerals in potatoes. *Journal of Food Science*, *73*(5), 80–85.

Blessington, T., Nzaramba, M. N., Scheuring, D. C., Hale, A. L., Reddivari, L., & Miller, J. C. (2010). Cooking methods and storage treatments of potato: Effects on carotenoids, antioxidant activity, and phenolics. *American Journal of Potato Research*, *87*(6), 479–491.

Brat, P., Tourniaire, F., & Amiot-Carlin, M. J. (2008). Stability and analysis of phenolic pigments. C. Socaciu (Ed.), *Food colorants: Chemical and functional properties*. Florida, United States,: CRC Press. pp 71–86.

Brown, C. R., Durst, R. W., Wrolstad, R., & De, J. W. (2008). Variability of phytonutrient content of potato in relation to growing location and cooking method. *Potato Research, 51*(3/4), 259–270.

Bureau, S., Mouhoubi, S., Touloumet, L., Garcia, C., Moreau, F., Bedouet, V., et al. (2015). Are folates, carotenoids and vitamin C affected by cooking? Four domestic procedures are compared on a large diversity of frozen vegetables. *LWT-Food Science and Technology, 64*(2015), 735–741.

Burgos, G., Amoros, W., Muñoa, L., Sosa, P., Cayhualla, E., Sanchez, C., et al . (2013). Total phenolic, total anthocyanin and phenolic acid concentrations and antioxidant activity of purple-fleshed potatoes as affected by boiling. *Journal of Food Composition and Analysis*, *30*(1), 6–12.

Burmeister, A., Bondiek, S., Apel, L., KŸhne, C., Hillebrand, S., & Fleischmann, P. (2011). Comparison of carotenoid and anthocyanin profiles of raw and boiled *Solanum tuberosum* and *Solanum phureja* tubers. *Journal of Food Composition and Analysis*, *24*(6), 865–872.

Cai, Y., Luo, Q., Sun, M, & Corke, H. (2004). Antioxidant activity and phenolic compounds of 112 traditional Chinese medicinal plants associated with anticancer. *Life Sciences*, *74*(17), 2157–2184.

Chaovanalikit, A., & Wrolstad, R. E. (2004). Total anthocyanins and total phenolics of fresh and processed cherries and their antioxidant properties. *Journal of Food Science*, *69*, FCT67–FCT72.

Chen, K., & Roca, M. (2018). Cooking effects on chlorophyll profile of the main edible seaweeds. *Food Chemistry*, *266*, 368-374.

Chen X.X., Leung G.P., Zhang Z.J., Xiao J.B., Lao L.X., Feng F., Mak J.C., Wang Y., Sze S.C., Zhang K.Y. (2017a). Proanthocyanidins from *Uncaria rhynchophylla* induced apoptosis in MDA-MB-231 breast cancer cells while enhancing cytotoxic effects of 5-fluorouracil. *Food and Chemical Toxicology*, *107*, 248-260.

Chen X.X., K.H. Lam, Q.X. Chen, G.P.H. Leung, S.C.W. Tang, S.C.W. Sze, J.B. Xiao, F Feng, Y Wang, KYB Zhang. (2017b). *Ficus virens* proanthocyanidins induced apoptosis in breast cancer cells concomitantly ameliorated 5-fluorouracil induced intestinal mucositis in rats. *Food and Chemical Toxicology*, *110*, 49-61.

Cheng, J., Chen, X., Zhao, S., & Zhang, Y. (2015). Antioxidant-capacity-based models for the prediction of acrylamide reduction by flavonoids. *Food Chemistry*, *168*, 90–99.

Cheong, T. K., Hwang, E., & Hyong, L. (2005). Reducing acrylamide in fried snack products by adding amino acids. *Journal of Food Science*, *70*, 354–357.

Chuah, A. M., Lee, Y. C., Yamaguchi, T., Takamura, H., Yin, L. J., & Matoba, T. (2008). Effect of cooking on the antioxidant properties of coloured peppers. *Food Chemistry*, *111*, 20–28.

Costa, C., Tsatsakis, A., Mamoulakis, C., Teodoro, M., Briguglio, G., Caruso, E., Tsoukalas, D., Margina, D., Dardiotis, E., Kouretas, D. (2017). Current evidence on the effect of dietary polyphenols intake on chronic diseases. *Food and Chemical Toxicology*, *110*, 286-299.

Daniali, G., Jinap, S., Hajeb, P., Sanny, M., & Tan, C. P. (2016). Acrylamide formation in vegetable oils and animal fats during heat treatment. *Food Chemistry*, *212*, 244–249.

De Paula, R., Rabalski, I., Messia, M. C., Abdel-Aal, E. M., & Marconi, E. (2017). Effect of processing on phenolic acids composition and radical scavenging capacity of barley pasta. *Food Research International*, *102*, 136–143.

De Sa, M. C., & Rodriguez-Amaya, D. B. (2003). Carotenoid composition of cooked green vegetables from restaurants. *Food Chemistry*, *83*, 595–600.

De Santiago E., Domínguez-Fernández, M., Cid, C., & De Peña, M. P. (2018). Impact of cooking process on nutritional composition and antioxidants of cactus cladodes (*Opuntia ficus-indica*). *Food Chemistry*, *240*, 1055–1062.

Dekker, M., Verkerk, R., & Jongen, W. M. F. (2000). Predictive modelling of health aspects in the food production chain: A case study on glucosinolates in cabbage. *Trends in Food Science and Technology*, *11*, 174–181.

Dhingra, D., Michael, M., Rajput, H., & Patil, R. T. (2012). Dietary fibre in foods: A review. *Journal of Food Science and Technology*, *49*, 255–266.

Dlamini, N. R., Taylor, J. R. N., & Rooney, L. W. (2007). The effect of sorghum type and processing on the antioxidant properties of African sorghum-based foods. *Food Chemistry*, *105*, 1412–1419.

Dolkar, P., Dolkar, D., Angmo, S., Kumar, B., Stobdan, T. (2017). Variability in phenolics, flavonoids and antioxidants in Seabuckthorn (Hippophae rhamnoides L.) seed from nine trans-Himalayan natural population. *Journal of Berry Research*, *7*, 109-116.

Embuscado, M. E. (2015). Spices and herbs: Natural sources of antioxidants-a mini review. *Journal of Functional Foods*, *18*, 811–819.

Espinosa-Diez, C., Miguel, V., Mennerich, D., Kietzmann, T., Sánchez-Pérez, P., Cadenas, S., et al. (2015). Antioxidant responses and cellular adjustments to oxidative stress. *Redox Biology*, *6*, 183–197.

Ezekiel, R., Singh, N., Sharma, S., & Kaur, A. (2013). Beneficial phytochemicals in potato-a review. *Food Research International*, *50*(2), 487–496.

Faller, A. L. K., & Fialho, E. (2009). The antioxidant capacity and polyphenol content of organic and conventional retail vegetables after domestic cooking. *Food Research International*, *42*(1), 210–215.

Fares, C., Platani, C., Baiano, A., & Menga, V. (2010). Effect of processing and cooking on phenolic acid profile and antioxidant capacity of durum wheat pasta enriched with debranning fractions of wheat. *Food Chemistry*, *119*(3), 1023–1029.

Fernanda, M. F., Roleira, E. J., Tavares-da-Silva, C. L., Varela, S. C. C., Tiago, S., Jorge, G., et al. (2015). Plant derived and dietary phenolic antioxidants: anticancer properties. *Food Chemistry*, *183*, 235–258.

Francisco, M., Velasco, P., Moreno, D. A., Cristina, G. V., & Cartea, M. E. (2010). Cooking methods of *Brassica rapa* affect the preservation of glucosinolates, phenolics and vitamin C. *Food Research International*, *43*, 1455–1463.

Friedman, M. (2015). Acrylamide: Inhibition of formation in processed food and mitigation of toxicity in cells, animals, and humans. *Food and Function*, *6*, 1752–1772.

Fuhr, U., Boettcher, M. I., Kinzig-Schippers, M., Weyer, A., Jetter, A., Lazar, A., et al. (2006). Toxicokinetics of acrylamide in humans after ingestion of a defined dose in a test meal to improve risk assessment for acrylamide carcinogenicity. *Cancer Epidemiol*

Biomarkers Prev, *15*, 266–271.

Giallourou, N., Oruna-Concha, M. J., & Harbourne, N. (2016). Effects of domestic processing methods on the phytochemical content of watercress (*Nasturtium officinale*). *Food Chemistry*, *212*, 411–419.

Girgin, N., & Sedef, N. E. (2015). Effects of cooking on *in vitro* sinigrin bioaccessibility, total phenols, antioxidant and antimutagenic activity of cauliflower (*Brassica oleraceae* L. var. *Botrytis*). *Journal of Food Composition and Analysis*, *37*, 119–127.

Gliszczyńska-Świgło, A., Ciska, E., Pawlak-Lemańska, K., Chmielewski, J., Borkowski, T., & Tyrakowska, B. (2006). Changes in the content of health-promoting compounds and antioxidant activity of broccoli after domestic processing. *Food Additives and Contaminants*, *23*, 1088–1098.

Gonçalves, E. M., Pinheiro, J., Abreu, M., Brandão, T. R. S., & Silva, C. L. M. (2010). Carrot (*Daucus carota* L.) peroxidase inactivation, phenolic content and physical changes kinetics due to blanching. *Journal of Food Engineering*, *97*, 574–581.

Harakotr B., Suriharn, B., Tangwongchai, R., Scott, M. P., & Lertrat, K. (2014). Anthocyanin, phenolics and antioxidant activity changes in purple waxy corn as affected by traditional cooking. *Food Chemistry*, *164*, 510–517.

Henle, T. (2005). Protein-bound advanced glycation end products (AGEs) as bioactive amino acid derivatives in foods. *Amino Acids*, *29*, 313–322.

Hidalgo, F., & Zamora, R. (2017). Food processing antioxidants. *Advances in Food and Nutrition Research*, *81*, 31–64.

Hossain A., Khatun, M. A., Islam, M., & Islam, R. (2017). Enhancement of antioxidant quality of green leafy vegetables upon different cooking method. *Preventive Nutrition and Food Science*, *22*(3), 216–222.

Jia, C. G., Xu, C. J., Wei, J., Yuan, J., Yuan, G. F., Wang, B. L., et al. (2009). Effect of modified atmosphere packaging on visual quality and glucosinolates of broccoli florets. *Food Chemistry*, *114*, 28–37.

Jones, R. B. (2007). Effects of postharvest handling conditions and cooking on anthocyanin, lycopene, and glucosinolate content and bioavailability in fruits and vegetables. *New Zealand Journal of Crop and Horticultural Science*, *35*(2), 219–227.

Kabat, G. C., Kim, M., Adams-Campbell, L. L., Caan, B. J., Chlebowski, R. T., Shikany, M.L., et al. (2009). Longitudinal study of serum carotenoid, retinol, and tocopherol concentrations in relation to breast cancer risk among postmenopausal women. *American Journal of Clinical Nutrition, 90*, 162–169.

Kamiloglu, S., Demirci, M., Selen, S., Toydemir, G., Boyacioglu, D., & Capanoglu, E. (2014). Home processing of tomatoes (*Solanum lycopersicum*): Effects on in vitro bioaccessibility of total lycopene, phenolics, flavonoids, and antioxidant capacity. *Journal of the Science of Food and Agriculture*, *94* (11), 2225–2233.

Kao, F. G., Chiu, Y. S., & Chiang, W. D. (2014). Effect of water cooking on antioxidant capacity of carotenoid-rich vegetables in Taiwan. *Journal of Food and Drug Analysis*, *22*, 202–209.

Kao, F. G., Chiu, Y. S., Tsou, M. J., & Chiang, W. D. (2012). Effects of Chinese domestic cooking methods on the carotenoid composition of vegetables in Taiwan. *LWT-Food Science and Technology*, *46*, 485–492.

Kapusta-Duch, J., Kusznierewicz, B., Leszczyńska, T., & Borczak, B. (2016). Effect of cooking on the contents of glucosinolates and their degradation products in selected *Brassica*, vegetables. *Journal of Functional Foods*, *23*, 412–422.

Karas, D., Ulrichova, J., Valentova, K. (2017). Galloylation of polyphenols alters their biological activity. *Food and Chemical Toxicology*, *105*, 223-240.

Ke, Z. L., Pan, Y., Xu, X. D., Nie, C., & Zhou, Z. Q. (2015). Citrus flavonoids and human cancers. *Journal of Food and Nutrition Research*, *3*(5), 341–351.

Kim, J., Cha, Y. N., & Surh, Y. J. (2010). A protective role of nuclear factor-erythroid 2-related factor-2 (Nrf2) in inflammatory disorders. *Mutation Research, 690*(2), 12–23.

Kita, A., Bąkowska-Barczak, A., Hamouz, K., Kułakowska, K., & Lisińska, G. (2013). The effect of frying on anthocyanin stability and antioxidant activity of crisps from red- and purple-fleshed potatoes (*Solanum tuberosum* L.). *Journal of Food Composition and Analysis*, *32*(2), 169–175.

Kosinska-Cagnazzo, A., Weber, B., Chablais, R., Vouillamoz, J.F., Molnar, B., Crovadore, J., Lefort, F., Andlauer, W. (2017). Bioactive compound profile and antioxidant activity of fruits from six goji cultivars cultivated in Switzerland. *Journal of Berry Research, 7,* 43-59.

Krishnaiah, D., Sarbatly, R., & Nithyanandam, R. (2010). A review of the antioxidant potential of medicinal plant species. *Food and Bioproducts Processing*, *89*, 217–233.

Kumar, G., Kumeshini, S., & Xu, B. J. (2017). Impact of consumption of repeatedly heated cooking oils on the incidence of various cancers-A critical review. *Critical Reviews in Food Science and Nutrition*, DOI: 10.1080/10408398.2017.1379470

Kushi, L. H., Doyle, C., McCullough, M., Rock, C. L., Demark-Wahnefried, Bandera, W., E. V., Gapstur, S., Patel, A. V., Andrews, K., Gansler, T., and The American Cancer Society 2010 Nutrition and Physical Activity Guidelines Advisory Committee. (2012). American Cancer Society guidelines on nutrition and physical activity for cancer prevention: Reducing the risk of cancer with healthy food choices and physical activity. *CA: A Cancer Journal for Clinicians*, *62*, 30–67.

Lachman, J., Hamouz, K., Musilová, J., Hejtmánková, K., Kotíková, Z., Pazderů, K., et al. (2013). Effect of peeling and three cooking methods on the content of selected phytochemicals in potato tubers with various colour of flesh. *Food Chemistry*, *138*, 1189–1197.

Lachman, J., Hamouz, K., Orsák, M., Pivec, V., Hejtmánková, K., Pazderů, K., et al. (2012). Impact of selected factors-cultivar, storage, cooking and baking on the content of anthocyanins in coloured-flesh potatoes. *Food Chemistry*, *133*(4), 1107–1116.

Lambeth, J. D. (2004). NOX enzymes and the biology of reactive oxygen. *Nature Reviews Immunology*, *4*, 181–189.

Lemos, M. A., Aliyu, M. M., & Hungerford, G. (2012). Observation of the location and form of anthocyanin in purple potato using time-resolved fluorescence. *Innovative Food Science and Emerging Technologies*, *16*, 61–68.

Lemos, M. A., Aliyu, M. M., & Hungerford, G. (2015). Influence of cooking on the levels of bioactive compounds in purple majesty potato observed via chemical and spectroscopic means. *Food Chemistry*, *173*, 462–467.

Li, K.S., Ali, A., & Muhammad, I. I. (2017). The influence of microwave cooking on the nutritional composition and antioxidant activity of the underutilized perah seed. *Acta Scientiarum Polonorum Technologia Alimentaria*, *16*(3), 283–292.

Lin, C. H., & Chang, C. Y. (2005). Textural change and antioxidant properties of broccoli under different cooking treatments. *Food Chemistry*, *90*(1–2), 9–15.

Loizzo, M. R., Pugliese, A., Bonesi, M., Luca, D. D., O'Brien, N., Menichini, F., et al. (2013). Influence of drying and cooking process on the phytochemical content, antioxidant and hypoglycaemic properties of two bell *Capsicum annum* L. cultivars. *Food and Chemical Toxicology*, *53*, 392–401.

Luo X.L., Wang Q., Zheng B.D., Lin L.M., Chen B.Y., Zheng Y.F., Xiao J.B. (2017). Hydration properties and binding capacities of dietary fibers from bamboo shoot shell and its hypolipidemic effects in mice. *Food and Chemical Toxicology*, *109*, 1003-1009.

Mallebrera, B., Maietti, A., Tedeschi, P., Font, G., Ruiz, MJ., Brandolini, V. (2017). Antioxidant capacity of trans-resveratrol dietary supplements alone or combined with the mycotoxin beauvericin. *Food and Chemical Toxicology*, *105*, 315-318.

Manzocco, L., Calligaris, S., Mastrocola, D., Nicoli, M. C., & Lerici, C. R. (2001). Review of non-enzymatic browning and antioxidant capacity in processed foods. *Trends in Food Science and Technology*, *11*, 340–346.

Mazzeo, T., N'Dri, D., Chiavaro, E., Visconti, A., Fogliano, V., & Pellegrini, N. (2011). Effect of two cooking procedures on phytochemical compounds, total antioxidant capacity and colour of selected frozen vegetables. *Food Chemistry*, *128*, 627–633.

Michalska, A., Carlen, C., Heritier, J., Andlauer, W. (2017). Profiles of bioactive compounds in fruits and leaves of strawberry cultivars. *Journal of Berry Research*, *7*, 71-84.

Miglio, C., Chiavaro, E., Visconti, A., Fogliano, V., & Pellegrini, N. (2008). Effects of different cooking methods on nutritional and physicochemical characteristics of selected vegetables. *Journal of Agricultural and Food Chemistry*, *56*, 139–147.

Milán-Noris, A. K., Gutiérrez-Uribe, J. A., Santacruz, A., Serna-Saldívar, S. O., & C. Martínez-Villaluenga. (2018). Peptides and isoflavones in gastrointestinal digests contribute to the anti-inflammatory potential of cooked or germinated Desi and Kabuli chickpea (*Cicer arietinum*, L.). *Food Chemistry*, *268*, 66–76.

Mogol, B. A., & Gokmen, V.. (2016). Thermal process contaminants: Acrylamide, chloropropanols and furan. *Current Opinion in Food Science*, *7*, 86–92.

Monero, D. A., Perez-Balibrea, S., Ferreres, F., Gil-Izquierdo, A., & García-Viguera, C. (2010). Acylated anthocyanins in broccoli sprouts. *Food Chemistry, 123*(2), 358–363.

Morales, G., Jimenez, M., Garcia, O., Mendoza, M. R., & Beristain, C. I. (2014). Effect of natural extracts on the formation of acrylamide in fried potatoes. *LWT-Food Science and Technology, 58*, 587–593.

Moreno, D. A., Lopez-Berenguer, C., & Garcia-Viguera, C. (2007). Effects of stir-fry cooking with different edible oils on the phytochemical composition of broccoli. *Journal of Food Science, 72*, S64–S68.

Motohashi, H., & Yamamoto, M. (2004). Nrf2-Keap1 defines a physiologically important stress response mechanism. *Trends in Molecular Medicine*, *10*(11), 549–557.

Mottram, D. S., Wedzicha, B. L., & Dodson, A. T. (2002). Acrylamide is formed in the Maillard reaction. *Nature, 419*, 448–449.

Murador, D. C., Cunha, D. T. D., & Rosso, V. V. D. (2014). Effects of cooking techniques on vegetable pigments: a meta-analytic approach to carotenoid and anthocyanin levels. *Food Research International*, *65*, 177–183.

Murniece, I., Karklina, D., Galoburda, R., Santare, D., Skrabule, I., & Costa, H. S. (2011). Nutritional composition of freshly harvested and stored Latvian potato (*Solanum tuberosum* L.) varieties depending on traditional cooking methods. *Journal of Food Composition and Analysis*, *24*, 699–710.

Myung, S. K., Ju, W., Choi, H. J., & Kim, S. C. (2009). Soy intake and risk of endocrine-related gynaecological cancer: a meta-analysis. *International Journal of Gynecology and Obstetrics*, *116*, 1697–1705.

Nachi, I., Fhoula, I., Smida, I., Taher, I. B., Chouaibi, M., Jaunbergs, J., et al. (2018). Assessment of lactic acid bacteria application for the reduction of acrylamide formation in bread. *LWT-Food Science and Technology*, *92*, 435–441.

Nakao, K., Murata, K., Itoh, K., Hanamoto, Y., Masuda, M., Moriyama, K., et al. (2011). Anti-hyperuricemia effects of extracts of immature *Citrus unshiu* fruit. *Journal of Traditional Medicines*, *28*(1), 10–15.

Navarre, D. A., Shakya, R., Holden, J., & Kumar, S. (2010). The effect of different cooking methods on phenolics and vitamin C in developmentally young potato tubers.

American Journal of Potato Research, *87*(4), 350–359.

Nayak, B., Liu, R. H., & Tang, J. (2015). Effect of processing on phenolic antioxidants of fruits, vegetables, and grains-A review. *Critical Reviews in Food Science and Nutrition*, *55*, 887–918.

Neves, D.B.D., Caldas, E.D. (2017). Determination of of caffeine and identification of undeclared substances in dietary supplements and caffeine dietary exposure assessment. *Food and Chemical Toxicology*, *105*, 194-202.

Ng Z. X., & Tan, W. C. (2017). Impact of optimised cooking on the antioxidant activity in edible mushrooms. *Journal of Food Science and Technology*, *54*(12), 4100–4111.

Olivera-Castillo, L., Grant, G., Kantún-Moreno, N., Acevedo, J. J., Puc-Sosa, M., Montero, J., et al. (2018). Sea cucumber (*Isostichopus badionotus*) body-wall preparations exert anti-inflammatory activity *in vivo*. *PharmaNutrition*, *6*, 74–80.

Orellana-Palma, P., Petzold, G., Pierre, L., Pensaben, J.M. (2017). Protection of polyphenols in blueberry juice by vacuum-assisted block freeze concentration. *Food and Chemical Toxicology*, *109*, 1093-1102.

Paciulli, M., Dall'Asta, C., Rinaldi, M., Pellegrini, N., Pugliese, A., & Chiavaro, E. (2018). Application and optimisation of air-steam cooking on selected vegetables: impact on physical and antioxidant properties. *Journal of the Science of Food and Agriculture*, *98*(6), 2267–2276.

Pan, P., Skaer, C., Yu, J.H., Zhao, H., Ren, H., Oshima, K., Wang, L.S. (2017). Berries and other natural products in pancreatic cancer chemoprevention in human clinical trials. *Journal of Berry Research*, *7*, 147-161.

Palermo, M., Pellegrini, N., & Fogliano, V.. (2014). The effect of cooking on the phytochemical content of vegetables. *Journal of the Science of Food and Agriculture*, *94*(6), 1057–1070.

Pellegrini, N., Chiavaro, E., Gardana, C., Mazzeo, T., Contino, D., Gallo, M., et al. (2010). Effect of different cooking methods on color, phytochemical concentration, and antioxidant capacity of raw and frozen *Brassica* vegetables. *Journal of Agricultural and Food Chemistry*, *58*(7), 4310–4321.

Pérez-Nevado, F., Cabrera-Bañegil, M., Repilado, E., Martillanes, S., & Martín-Vertedor, D.

(2018). Effect of different baking treatments on the acrylamide formation and phenolic compounds in californian-style black olives. *Food Control*, 94, 22–29.

Perla, V., Holm, D. G., & Jayanty, S. S. (2012). Effects of cooking methods on polyphenols, pigments and antioxidant activity in potato tubers. *LWT-Food Science and Technology*, *45*(2), 161–171.

Pinela, J., Carvalho, A.M., Ferreira, I.C.F.R. (2017). Wild edible plants: Nutritional and toxicological characteristics, retrieval strategies and importance for today's society. *Food and Chemical Toxicology*, *110*, 165-188.

Poljsak, B., & Milisav, I. (2014). Oxidized forms of dietary antioxidants: Friends or foes? *Trends in Food Science and Technology*, *39*(2), 156–166.

Prodanov, M., Sierra, I., & Vidal-Valverde, C. (2004). Influence of soaking and cooking on the thiamin, riboflavin and niacin contents of legumes. *Food Chemistry*, *84* (2), 271–277.

Rajendran, P., Nandakumar, N., Rengarajan, T., Palaniswami, R., Gnanadhas, E. N., Lakshminarasaiah, U., et al. (2014). Antioxidants and human diseases. *Clinica Chimica Acta*, *436*, 332–347.

Rao, A. V., &. Rao, L. G. (2007). Carotenoids and human health. *Pharmacological Research*, *55*, 207–216.

Ravichandran, K., Ahmed, A. R., Knnor, D., & Smetanska, I. (2012). The effect of different processing methods on phenolic acid content and antioxidant activity of red beet. *Food Research International*, *48*, 16–20.

Redondo, D., Venturini, M. E., Oria, R., & Arias, E. (2016). Inhibitory effect of microwaved thinned nectarine extracts on polyphenol oxidase activity. *Food Chemistry*, *197*, 603–610.

Reis, L. C. R. D., Oliveira, V. R. D., Hagen, M. E. K., Jablonski, A., Flôres, S. H., & Rios, A. D. O. (2015). Carotenoids, flavonoids, chlorophylls, phenolic compounds and antioxidant activity in fresh and cooked broccoli (*Brassica oleracea*, var. *avenger*) and cauliflower (*Brassica oleracea*, var. *alphina* f1). *LWT-Food Science and Technology*, *63*(1), 177–183.

Rius, J., Guma, M., Schachtrup, C., Akassoglou, K., Zinkernagel, A. S., Nizet, V., et al.

(2008). NF-kappaB links innate immunity to the hypoxic response through transcriptional regulation of HIF-1alpha. *Nature*, *453*(7196), 807–811.

Rothwell, J. A., Medina-Remón, A., Pérez-Jiménez, J., Neveu, V., Knaze, V., Slimani, N., et al. (2015). Effects of food processing on polyphenol contents: A systematic analysis using phenol-explorer data. *Molecular Nutrition and Food Research*, *59*(1), 160–170.

Ruiz-Rodriguez, A., Marín, F. R., Ocańa, A., & Soler-Rivas, C. (2008). Effect of domestic processing on bioactive compounds. *Phytochemistry Reviews*, *7*(2), 345–384.

Sánchez, C., Baranda, A. B., & Marañón, I. M. (2014). The effect of high pressure and high temperature processing on carotenoids and chlorophylls content in some vegetables. *Food Chemistry*, *163*, 37–45.

Santhakumar, A.B., Battino, M., Alvarez-Suarez, J.M. (2017). Dietary polyphenols: Structures, bioavailability and protective effects against atherosclerosis. *Food and Chemical Toxicology*, *113*, 49-65.

Santos, M. C., Nunes, C., Rocha, M. A. M., Rodrigues, A., Rocha, S. M., Saraiva, J. A., et al. (2015). High pressure treatments accelerate changes in volatile composition of sulphur dioxide-free wine during bottle storage. *Food Chemistry*, *188*, 406–414.

Sarkar, D., Agustinah, W., Woods, F., Coneva, E., Vinson, E., Shetty, K. (2017). In vitro screening and evaluation of phenolic antioxidant-linked anti-hyperglycemic functions of rabbit-eye blueberry (Vaccinium ashei) cultivars. *Journal of Berry Research*, *7*, 163-177.

Schwartz, S. J., & Elbe, J. H. V. (2010). Kinetics of chlorophyll degradation to pyropheophytin in vegetables. *Journal of Food Science*, *48*, 1303–1306.

Sharma, P., Ramchiary, M., Samyor, D., & Das, A. B. (2016). Study on the phytochemical properties of pineapple fruit leather processed by extrusion cooking. *LWT-Food Science and Technology*, *72*, 534–543.

Shishu & Kaur, I. P. (2008). Antimutagenicity of curcumin and related compounds against genotoxic heterocyclic amines from cooked food: The structural requirement. *Food Chemistry*, *111*, 573–579.

Singh, B., Singh, J. P., Kaur, A., & Singh, N. (2017). Phenolic composition and antioxidant potential of grain legume seeds: a review. *Food Research International*, *101*, 1–16.

Singh, S., Swain, S., Singh, D., Salim, K., Nayak, D. & Roy, S. D. (2015). Changes in phytochemicals, anti-nutrients and antioxidant activity in leafy vegetables by microwave boiling with normal and 5% NaCl solution. *Food Chemistry*, *176*, 244–253.

Somsub, W., Kongkachuichai, R., Sungpuag, P., & Charoensiri, R. (2008). Effects of three conventional cooking methods on vitamin c, tannin, myo-inositol phosphates contents in selected thai vegetables. *Journal of Food Composition and Analysis*, *21*(2), 187–197.

Song, L., & Thornalley, P. J. (2007). Effect of storage, processing and cooking on glucosinolate content of brassica vegetables. *Food and Chemical Toxicology*, *45*, 216–224.

Sun, H., Mu, T., Xi, L., & Song, Z. (2014). Effects of domestic cooking methods on polyphenols and antioxidant activity of sweet potato leaves. *Journal of Agricultural and Food Chemistry*, *62*(36), 8982–8989.

Tang, Y., Cai, W., & Xu, B. (2016). From rice bag to table: fate of phenolic chemical compositions and antioxidant activities in waxy and non-waxy black rice during home cooking. *Food Chemistry*, *191*, 81–90.

Teng H., Lin Q.Y., Li K., Yuan B.Y., Song H.B., Yi L.Z., Wei M.C., Yang Y.C., Battino M., Acuña C.L.C., Chen L., Xiao J.B. (2017). Hepatoprotective effects of raspberry (*Rubus coreanus* Miq.) seed oil and its major constituents. *Food and Chemical Toxicology*, *110*, 418-424.

Tian, J. H., Chen, J. C., Ye, X. Q., & Chen, X. G. (2016b). Health benefits of the potato affected by domestic cooking: A review. *Food Chemistry*, *202*, 165–175.

Tian, J. H.,. Chen, J. L, Lv, F. Y., Chen, S. G., Chen, J. C., Liu, D. H., et al. (2016a). Domestic cooking methods affect the phytochemical composition and antioxidant activity of purple-fleshed potatoes. *Food Chemistry*, *197*, 1264–1270.

Tiwari, U., & Cummins, E. (2013). Factors influencing levels of phytochemicals in selected fruit and vegetables during pre- and post-harvest food processing operations. *Food Research International*, *50*(2), 497–506.

Vallejo, F., Tomás-Barberán, F. A., & Garcia-Viguera, C. (2002). Glucosinolates and vitamin C content in edible parts of broccoli florets after domestic cooking. *European Food Research and Technology*, *215*(4), 310–316.

Vallejo, F., Tomás-Barberán, F. A., & García-Viguera, C. (2003). Phenolic compound contents in edible parts of broccoli inflorescences after domestic cooking. *Journal of the Science of Food and Agriculture, 83*(14), 1511–1516.

Van Boeckel, M., Fogliano, V., Pellegreini, N., Stanton, C., Scholz, G., Lalljie, S., et al. (2010). A review on the beneficial aspects of food processing. *Molecular Nutrition and Food Research*, *54*, 1215–1247.

Verkerk, R., & Dekker, M. (2004). Glucosinolates and myrosinase activity in red cabbage (*Brassica oleracea* L. var. *Capitata* f. rubra DC.) after various microwave treatments. *Journal of Agricultural and Food Chemistry*, *52*, 7318–7323.

Verkerk, R., Schreiner, M., Krumbein, A., Ciska, E., Holst, B., Rowland, I., et al. (2009). Glucosinolates in *Brassica* vegetables: the influence of the food supply chain on intake, bioavailability and human health. *Molecular Nutrition and Food Research, 53,* S219–S265.

Williams, D. J., Edwards, D., Hamernig, I., Jian, L., James, A. P., Johnson, S. K., et al. (2013). Vegetables containing phytochemicals with potential anti-obesity properties: A review. *Food Research International*, *52*(1), 323–333.

Wong F.C., Chai T.T., Xiao J.B. (2018). The influences of thermal processing on phytochemicals and possible routes to the discovery of new phytochemical conjugates. *Critical Reviews in Food Science and Nutrition*, Doi: 10.1080/10408398.2018.1479681.

Wu, X. L., Sun, J. H., Haytowitz, D. B., Harnly, J. M., Chen, P., & Pehrsson, P. R.. (2017). Challenges of developing a valid dietary glucosinolate database. *Journal of Food Composition and Analysis*, DOI: 10.1016/j.jfca.2017.07.014.

Wu, S.Q., Li, J., Wang, Q.X., Cao, H., Cao, J.G., Xiao J.B. (2017). Seasonal dynamics of phytochemical contents and bioactivities of *Stenoloma chusanum*. *Food and Chemical Toxicology, 108*, 458-466.

Xiao, J.B. (2017). Dietary flavonoid aglycones and their glycosides: What show better biological benefits? *Critical Reviews in Food Science and Nutrition, 57,* 1874-1905.

Xu, F., Orunaconcha, M. J., & Elmore, J. S. (2016). The use of asparaginase to reduce acrylamide levels in cooked food. *Food Chemistry*, *210*, 163–171.

Xu, F., Zheng, Y. H., Yang, Z. F., Cao, S. F., Shao, X. F., & Wang, H. F. (2014). Domestic cooking methods affect the nutritional quality of red cabbage. *Food Chemistry*, *161*, 162–167.

Xu, X., Li, W., Lu, Z., Beta, T., & Hydamaka, A. W. (2009.) Phenolic content, composition, antioxidant activity, and their changes during domestic cooking of potatoes. *Journal of Agricultural and Food Chemistry, 57*(21), 10231–10238.

Zamora, R., León, M. M., & Hidalgo, F. J. (2015). Oxidative versus non-oxidative decarboxylation of amino acids: Conditions for the preferential formation of either Strecker aldehydes or amines in amino acid/lipid-derived reactive carbonyl model systems. *Journal of Agricultural and Food Chemistry*, *63*, 8037–8043.

Zhang B., Deng, Z., Tang, Y., Chen, P. X., Liu, R., Ramdath, D. D., et al. (2014a). Effect of domestic cooking on carotenoids, tocopherols, fatty acids, phenolics, and antioxidant activities of lentils (*Lens culinaris*). *Journal of Agricultural and Food Chemistry*, *62*(52), 12585–12594.

Zhang, C., Monk, J. M., Lu, J. T., Zarepoor, L., Wu, W., Liu, R., et al. 2014b. Cooked navy and black bean diets improve biomarkers of colon health and reduce inflammation during colitis. *British Journal of Nutrition*, *111*, 1549–1563.

Zhang, D., & Hamauzu, Y. (2004). Phenolics, ascorbic acid, carotenoids and antioxidant activity of broccoli and their changes during conventional and microwave cooking. *Food Chemistry*, *88*, 503–509.

Zhang, H., Xi, W., Yang, Y., Zhou, X., Liu, X., Yin, S., et al. (2015). An on-line HPLC-FRSD system for rapid evaluation of the total antioxidant capacity of *Citrus fruits*. *Food Chemistry*, *172*, 622–629.

Zhang, X., Tao, N., Wang, X., Chen, F., & Wang, M. (2015). The colorants, antioxidants, and toxicants from nonenzymatic browning reactions and the impacts of dietary polyphenols on their thermal formation. *Food and Function*, *6*, 345–355.

Zhang, Y., Huang, M., Wang, Q., & Cheng, J. (2016). Structure-guided unravelling: phenolic hydroxyls contribute to reduction of acrylamide using multiplex quantitative structure-activity relationship modelling. *Food Chemistry*, *199*, 492–501.

Zhao, C., Yang, C., Liu, B., Lin, L., Sarker, S. D., Nahar, L., et al. (2018). Bioactive compounds from marine macroalgae and their hypoglycemic benefits. *Trends in Food Science and Technology*, 72, 1–12.

Table 1. Effects of different domestic cooking methods on proximate composition.

Cooking methods	Cooking condition	Proximate composition changes	References
Boiling	100□, 20 min, penetrated easily	No significant changes in the crude fiber, ash, protein, and fat contents; Greatest losses were baking, followed by boiling, steaming and microwaving.	Tian, Chen, Ye, & Chen, 2016; Tian et al., 2016
Steaming	15 min, penetrated easily		
Microwaving	1000 W, 6 min, penetrated easily		
Baking	210□, 30 min, penetrated easily		
Frying	191□, 2 min; 300 g/3000 mL	Significantly increase the crude fat and crude fiber contents; Significantly decrease in the contents of ash; No significant change in the crude protein.	
Extrusion	Two barrel temperature profiles were selected: 40, 60, 80, 120, 120□ or 40, 60, 80, 120, 140□, from Zone 1 (feed port) to Zone 5 (exit die); Feed rate, screw speed, and total moisture content of the powder into the extruder were set at 2 kg/h, 100-200 rpm, and 25-30% using a water pump, respectively.	Reduce the content of protein; Crude fiber and ash were not determined.	Ai, Cichy, Harte, Kelly, & Perry, 2016
High-pressure	Fully dipped in 1500 mL of cold water and cooked during 5 min under high-pressure in a pressure cooker.	Reduce the ascorbic acid; The protein, ash and fiber were not determined.	Francisco, Velasco, Moreno, Cristina, & Cartea, 2010

Table 2. Effects of different domestic cooking methods on natural dietary phytochemicals

Vegetables	**Cooking methods**	**Phytochemicals changes**	**References**
Cilantro, Thai basil leaf, Sweet potato leaf, Choy sum	Boiling	□TCC of vegetables increased until it reached a maximum with the increase in boiling time and then decreased except choy sum. TCC of choy sum was not affected by boiling for 30 min cooking. □TPC↓ for cilantro and choy sum. TPC↑ for Thai basil leaf and sweet potato leaf during 1-5 min. The TPC decreased as the boiling time increased. □AAC↓.	Kao, Chiu, & Chiang, 2014
Green bean, Pea, Brussels sprout, Leek (slices), Broccoli, Zucchini (slices), Spinach branch, Hashed spinach, Yellow French bean, Cauliflower, Mushroom, Carrot (slices), Salsify	Boiling	□TCC↓; □AAC↓	Bureau et al., 2015
	Pressure cooking, steaming, microwaves	□TCC↑; □AAC↓	
Purple-fleshed potatoes	Boiling, steaming, microwaving, baking, frying	□TPC↓: The maximum losses were treated by baking, followed by frying, steaming, boiling, and microwaving. □TCC↓: The maximum losses were treated by frying, follow by microwaving, baking, steaming, and boiling. □TAC↓: The maximum losses were treated by frying, followed by steaming, boiling, microwaving, and baking.	Tian, Chen, Ye, & Chen, 2016; Tian et al., 2016
Cilantro, Thai basil leaf, Sweet potato leaf, Choy sum	Stir-frying, deep-frying	TCC↓	Kao, Chiu, Tsou, & Chiang, 2012
Potatoes	Baked non-peeled cut, microwaved non-peeled cut, boiled peeled	AAC↓: The maximum losses were treated by baked non-peeled cut, followed by microwaved non-peeled cut and boiled peeled.	Lachman et al., 2013
Red cabbages	Stir-frying, boiling, steaming, microwaving	□TAC↓: The maximum losses were treated by stir-frying, followed by boiling, microwaving, and steaming. □TPC and AAC↓: By stir-frying and boiling, while no changes with steaming and microwaving. □TGC↓: The maximum losses were treated by stir-frying and boiling, followed by microwaving and steaming.	Xu et al., 2014
Cauliflower	Steaming	TPC↑	Girgin & Nehir, 2015
	Boiling	TPC↓	
Broccoli	Boiling, steaming, microwaving,	□TCH (“*a*” and “*b*”) ↑; □TCC↑.	Reis et al., 2015

	sous vide		
Watercress	Boiling Steaming, microwaving	□TFC↓; □TCC↑ and TGC↓ No significant impacts for TFC, TCC, and TGC.	Giallourou, Oruna-Concha, & Harbourne, 2016
Potato tubers	Baking, microwaving	TFC↓	Perla, Holm, & Jayanty, 2012
Peppers	Boiling, microwaving, stir-fry	□AAC↓: The maximum losses were treated by boiling, followed by stir-fry and microwaving. □TCC↓.	Chuah et al., 2008
Spinach, Carrot	Boiling, steaming	TCC↓	Mazzeo, N’Dri, Chiavaro, Visconti, Fogliano, & Pellegrini, 2011
Pineapples	Extrusion	□TPC↓. □AAC↑ at initial stage; AAC↓: until temperature up to 82℃. ③TFC↓.	Sharma, Ramchiary, Samyor, & Das, 2016
Broccoli	Frying, microwaving, frying/microwaving, Steaming, baking	□TCH (“*a*” & “*b*”); □TCC↓ No significant impacts for TCH (“*a*” and “*b*”) and TCC.	Barakat & Rohn, 2014

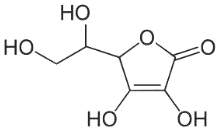
Note: “↑” and “↓” mean increase and decrease in contents of phytochemicals, respectively. TCC: Total carotenoid content; TPC: Total phenolic content; AAC: Ascorbic acid content; TGC: Total glucosinolates content; TAC: Total anthocyanin content; TFC: Total flavonoid content; TCH: Total chlorophylls content.

Table 3. Effects of different domestic cooking methods on antioxidant activities (AA) of foods.

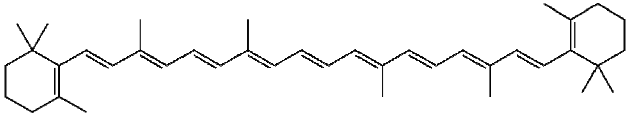
Vegetables	**Measuring methods**	**Cooking methods**	**Antioxidant activity changes**	**References**
Purple-fleshed potatoes	DPPH assay	Boiling; Microwaving; Frying; Steaming; Baking; Stir-frying	AA↓	Tian, Chen, Ye, & Chen, 2016; Tian et al., 2016
		Air-frying	AA↑	
Purple waxy corn	ABTS	Boiling	AA↓	Harakotr, Suriharn, Tangwongchai, Scott, & Lertrat, 2014
		Steaming	AA↑	
Lentils (*Lens culinaris)*	DPPH and ORAC assays	Boiling	A properly designed cooking protocol will not cause significant loss of the phytochemical antioxidants.	Zhang et al., 2014a
Edible mushrooms (*Agaricus bisporus*, *Flammulina velutipes*, *Lentinula edodes*, *Pleurotus ostreatus* and *Pleurotus eryngii*)	FRAP, TEAC and DPPH assays	Steaming	AA↑: for *F. velutipes*, *P. ostreatus* and *L. edodes*	Ng & Tan, 2017
		Microwaving	AA↑: for *A. Bisporus*	
		Pressure cooking	AA↑: for *P. eryngii*	
Perah seeds	DPPH and β-Carotene bleaching assays	Microwaving	AA↑: caused by solubilization of phenolic compounds and formation of Maillard reaction products.	Li, Ali, & Muhammad, 2017
Green leafy vegetables (garden spinach leaf, water spinach leaf, Indian spinach leaf, and green leaved amaranth)	DPPH assay	Boiling; Frying	AA↑: both cooking processes enhanced significantly the radical scavenging ability.	Hossain, Khatun, Islam, & Islam, 2017

Brussels sprouts, pumpkin cubes	DPPH assay	Air-steam cooking	AA↑	Paciulli et al., 2018
Cactus cladodes	ABTS and DPPH assays	Microwaving; Griddling Boiling	AA↑ AA↓	De Santiago, Domínguez-Fernández, Cid, & De Peña, 2018
Carrrot, Onion, Potato, Broccoli, White cabbage	DPPH assay	Boiling; Microwaving; Steaming	AA↓: for carrot, onion, and white cabbage AA↑: for potato and broccoli	Faller & Fialho, 2009
Cauliflower	ABTS, DPPH and phosphomolybdenum assays	Boiling Steaming	AA↓ AA↑	Girgin & Sedef, 2015
Watercress	FRAP assay	Boiling Steaming; Microwaving	AA↓ No significant losses for AA	Giallourou, Oruna-Concha, & Harbourne, 2016
Pineapple fruit leather	DPPH assay	Extrusion	AA↑	Sharma, Ramchiary, Samyor, & Das, 2016
Pepper	ABTS and DPPH assays	Frying	AA was no significantly decrease with DPPH assay, however, it has a drastically decrease by ABTS method.	Loizzo et al., 2013
Broccoli	DPPH assay	Boiling; Microwaving	AA↓	Zhang & Hamauzu, 2004

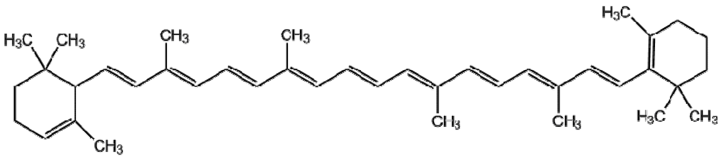
Note: “↑” and “↓” mean increase and decrease in contents of phytochemicals, respectively. ORAC, oxygen radical absorption capacity assay; FRAP, Ferric reducing antioxidant power; TEAC, Trolox equivalent antioxidant capacity.



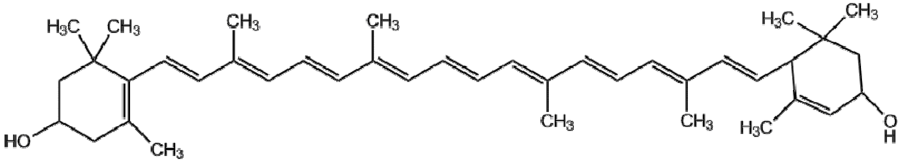
Ascorbic acid ***1***



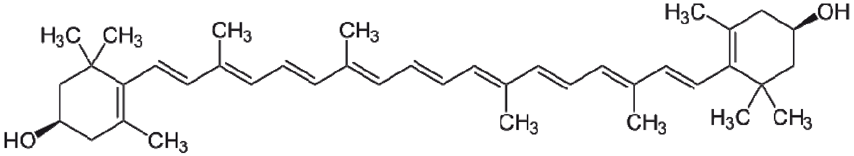
β-carotene ***2***



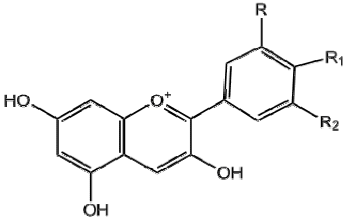
α-carotene ***3***



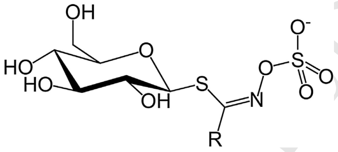
Lutein ***4***



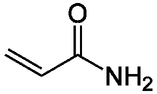
Zeaxanthin ***5***



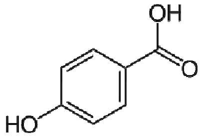
Anthocyanin ***6***



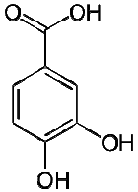
Glucosinolate ***7***



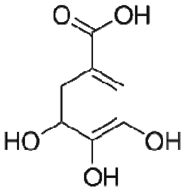
Acrylamide ***8***



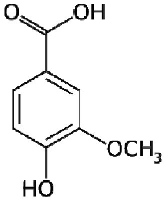
p-Hydroxybenzoic acid ***9***



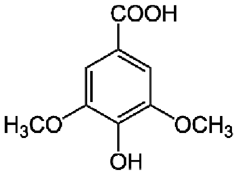
Protocatechuic acid ***10***



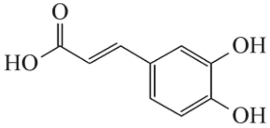
Gallic acid ***11***



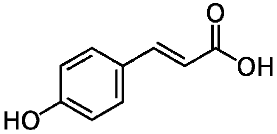
Vanillic acid ***12***



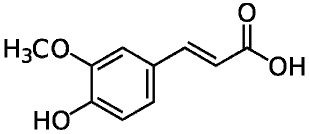
Syringic acid ***13***



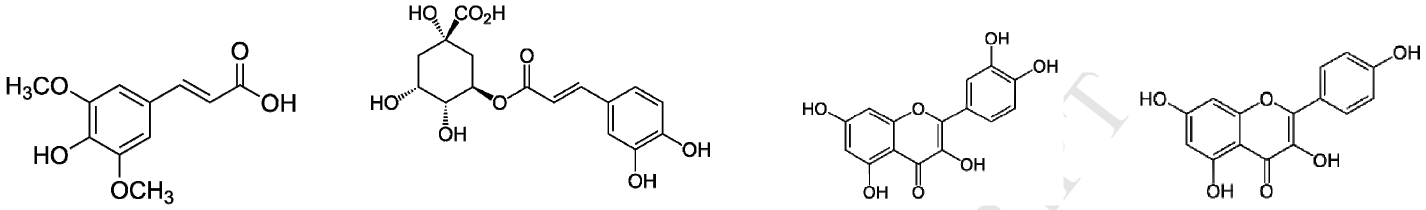
Caffeic acid ***14***



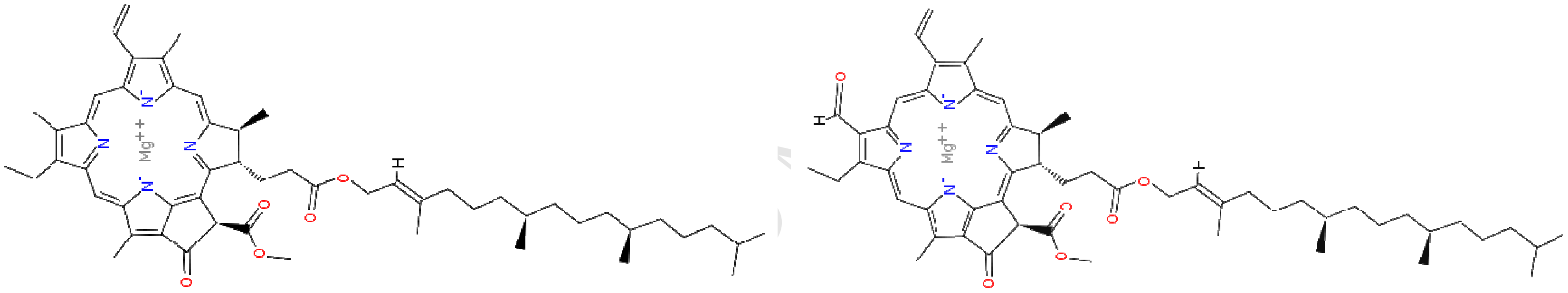
p-Coumaric acid ***15***



Ferulic acid ***16***



Sinapic acid ***17*** Chlorogenic acid ***18*** Quercetin ***19*** Kaempferol ***20***



Chlorophyll *a* ***21*** Chlorophyll *b* ***22***

Fig. 1. Chemical structures of dietary compounds.

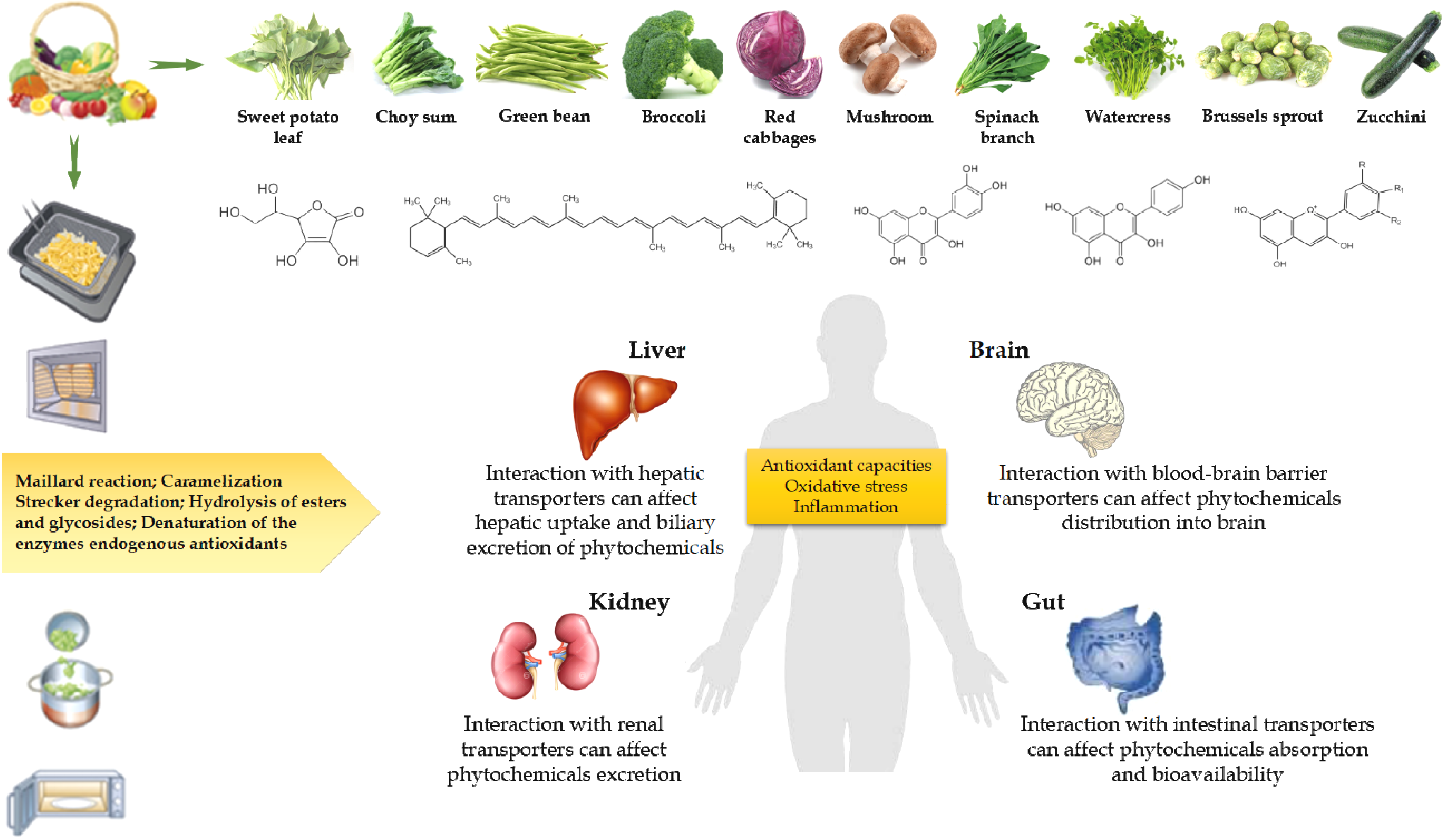


Fig. 2. Absorption and disposition of natural phytochemicals after food processing in humans. Vegetables and their associated phytochemicals appear to increase antioxidant capacities and concomitantly suppress oxidative stress and inflammation.

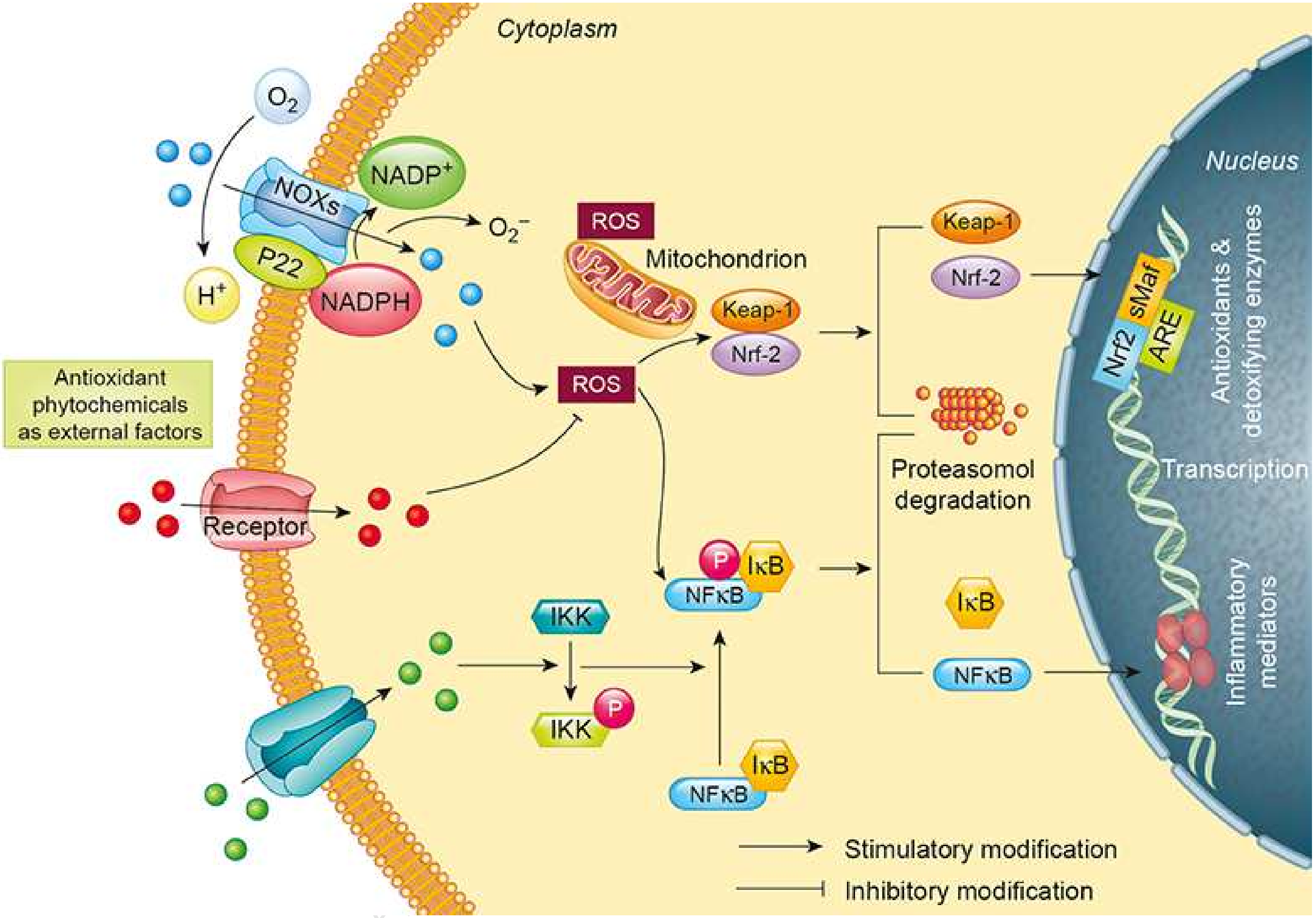


Fig. 3. The antioxidant responses and cellular adjustments with natural phytochemicals as antioxidants.

1. The domestic cooking methods affect the nutritional values and functional properties of foods. 2. The effect of structural changes with the release of nutrients and phytochemicals during cooking was mostly ignored.

3. The bioactive compounds can be beneficial or detrimental depending on the processing conditions.