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Variation in polyphenol content due to commonly applied processing techniques: A review

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Abstract
The present review is all about the effects of various commonly used processing methods in our country and is based upon the evaluation of previous studies depicting various food processing applications with its effects on raw ingredient. This review deals with various subclasses of phenolic compounds as phenolic acids, chalcones, flavanones, flavones, flavonols and tannins, and the changes these compounds undergo during processing. Health properties of poly-phenolic compounds are also discussed to emphasize their importance as integral part of our diet. After going through several researches it was found that the effect of same processing method can be different for different sub- classes of polyphenols and the effect can also vary according to variety of the raw ingredient. Most of the processing techniques such as blanching, boiling, microwaving etc. tend to degrade the quantity of polyphenols present in raw form but it was also seen that sometimes it increases the bioavailability of certain phytochemicals. Tables are provided to give a clear and more precise and focused view of polyphenol losses on application of various methods of processing.

Keywords: Food processing, polyphenols

Introduction
Polyphenols are a large class of chemicals which are found in plants, have grabbed much attention in the last decades due to their properties and beneficial health effects, when taken as a dietary constituent (Ming Hu, 2007) [48]. Phenolic compounds constitute one of the most extensive groups of chemicals in the plant kingdom. It is estimated that more than 8000 compounds have been isolated and described yet (Ramos, 2007) [64]. Polyphenols are secondary metabolites of plants and are generally involved in defense against ultraviolet radiation or aggression by pathogens (Pandey and Rizvi, 2009) [55]. Polyphenols may be classified into different groups as a function of the number of phenol rings that they contain and on the basis of structural elements that bind these rings to one another. The main classes include phenolic acids, flavonoids and stilbenes (Spencer *et al.*, 2008) [77]. The most common phenolics in human diet are phenolic acids, flavonoids and tannins (King and Young, 1999) [40]. Phenolic compounds have at least one aromatic ring with one or more hydroxyl groups, and may be classified as flavonoids and non-flavonoids (Del Rio *et al.*, 2012) [12].

Health benefits of polyphenols-
Polyphenols exert a protective action on human health and are key components of a healthy and balanced diet. Epidemiological studies correlate flavonoid intake with a reduced incidence of chronic diseases, such as cardiovascular disease, diabetes and cancer. An inverse association between the risk of chronic human diseases and the consumption of poly-phenolic rich diet is showcased (Lima *et al.*, 2014; Scarlbert *et al.*, 2005; Arts and Hollman, 2005) [43, 72, 6]. Phenols from numerous plant species have been actively studied as potential treatments for various metabolic and cardiovascular diseases. For example, resveratrol found in red wine (Ahn *et al.*, 2008; Szkudelska *et al.*, 2009) [3, 78], epigallocathechin-3-gallate from green tea (Li *et al.*, 2006; Potenza *et al.*, 2007) [43, 58], curcumin from turmeric (Ejaz *et al.*, 2009) [16] and quercetin (Egert *et al.*, 2009; Egert *et al.*, 2010) [15, 14] from different sources have all been studied as potential therapeutic agents. As antioxidants, polyphenols have ability to protect cell constituents against oxidative damage and, therefore, limit the risk of various degenerative diseases associated with oxidative stress as cancer, cardiovascular diseases etc. (Luqman and Rizvi, 2006, Pandey *et al.*, 2009) [46, 54]. Polyphenols may also exert antithrombotic effects by inhibiting platelet aggregation.

Consumption of red wine or nonalcoholic wine reduces bleeding time and platelet aggregation (Demrow *et al.*, 1995) [13]. Phenolic compounds may help to protect the gastrointestinal tract against damage by reactive species present in foods or generated within the stomach and intestines (Halliwell, 2007) [27]. Tea polyphenols tends to improve endothelial function which has blood pressure reducing effects. Polyphenols also exhibit some chemo preventive actions as anti-proliferation, induction of cell cycle arrest or apoptosis, prevention of oxidation, induction of detoxification enzymes, regulation of the host immune system, anti-inflammatory activity (Gracia Lafauente *et al.*, 2009) [22]. Tea catechins have been investigated for their anti-diabetic potential and were found to inhibit glucose absorption in gut and its uptake by peripheral tissues (Young *et al.*, 1999, Gee *et al.*, 1998) [86, 23]. Polyphenols are also beneficial in ameliorating the adverse effects of the aging on nervous system or brain (Harikumar and Aggarwal, 2008) [28]. These have ability to influence and modulate several cellular processes such as signaling, proliferation, apoptosis, redox balance and differentiation and thus impart neuro-protective effects (Singh *et al.*, 2008) [74].

Anti- oxidant
Anti- viral
Anti- bacterial
Anti- inflammatory
Anti- ischemic
Anti- carcinogenic
Anti- toxic
Anti- mutagenic
Anti- mutagenic
Free radicals scavenging properties
Prevents oxidative stress
Have lipid lowering effects
Prevents LDL oxidation

Fig 1: Health properties of polyphenols

Processing effects on overall polyphenol conten

Food processing often causes losses in polyphenol content, usually brought about by oxidation, enzymatic action, removal of skin or seeds, and leaching into oil or water that is then discarded (Rickman *et al.*, 2007) [65]. Jam and marmalade processing significantly decreased total phenolics (89.2–90.5%), antioxidant capacity (83.3–91.3%) and phenolic acids (49.5–96.7%) ($p<0.05$). In addition, jam and marmalade processing led to increases in the percent recovery of bio accessible total phenolics (7.2–12.6%) and phenolic acids (4.7–31.5%), as well as antioxidant capacity (1.4–8.1%) (Kamiloglua *et al.*, 2015) [37]. According to Andlauer *et al.* boiled, baked, and uncooked samples possess lower total phenolic content than the fried or microwaved samples in case of potatoes. Boiling of vegetables causes phenolic constituents to be leached into the cooking water and many phenolics are lost when this water is discarded (Andlauer *et al.*, 2003; Ismail *et al.*, 2004) [5, 31].

In a study conducted by Zhang *et al.* in 2004 [87] it was reported that broccoli lost up to 70% of its total phenolics content on wet weight basis after boiling or microwaving. 45% of total phenolic content was reduced when blanching was conducted at low temperature i.e. 80-90 °C for about 2 minutes which is less when compared to 50% loss that occurred upon blanching cabbage for same period of time at high temperature i.e. 95-100 °C (Jaiswal *et al.*, 2012) [32].

Abu- Ghannan and Jaiswal in 2015 [1] stated that the effect of the blanching temperature is of a less significance particularly within 80-100 °C. However, according to Podsedek *et al.* (2008) [57] shortening the conventional blanching time from 20 to 10 min increased the retention of phenolics by only 3.8-6.7%. Blessington *et al.* in 2010 [8] reported that microwaved samples of potatoes have high total polyphenol content levels than the boiled and uncooked samples. Puupponen-Pimi *et al.* in 2003 [62] studied the effects of blanching and freezing on phenolic compounds of peas, carrots, cauliflower, cabbage and potatoes. The authors reported an average loss of 20–30% DW of TPs in most vegetables, although no change was observed in most carrot samples and a 26% DW increase was observed in cabbage.

Blanching has a detrimental effect on the phenolic content of cabbage with losses in general exceeding 50% of the initial content in raw cabbage and according to Gonclaves *et al.* (2010) [26] these losses in polyphenol content are attributed to the disruption of the plant tissue due to the heating effect, leading into polyphenols leaching out into the blanching water.

Storage processes usually caused only minor changes in polyphenol content, although severe losses were noted in a few cases after storage at ambient temperature (Rothwell *et al.*, 2015) [68]. And the length of frozen storage time can also affect the polyphenol content of elderberry fruit juice (Johnson *et al.*, 2015; Mullen *et al.*, 2002) [35, 51].

Table 1: Effect of processing on total polyphenol content

Sr. no.	Raw Ingredient	Processing Method	Changes	References
1.	Cabbage	Blanching + Freezing	26% increase on dry weight basis	Puupponen-Pimi¨a *et al.* (2003) [62]
2.	Cherries	Stored at -70 °C for 6 months	Retained 100%	Chaovanalikit and Wrolstad (2004) [10]
3.	Clingstone peaches	Freezing	30% increase on wet weight basis	Asami *et al.* (2002) [7]
4.	Finger millet	Sprouting/ Pressure cooking	50% decrease	Hithamani and Srinivasan (2014) [29]
5.	Finger millet	Open pan boiling	12-19% decrease	Hithamani and Srinivasan (2014) [29]
6.	Finger millet	Roasting	17% increase	Hithamani and Srinivasan (2014) [29]
7.	Finger millet	Sprouting	67% increase in bio- accessible phenolics	Hithamani and Srinivasan (2014) [29]
8.	Finger millet	Microwave heating	25-32% decrease in bio-accessible polyphenols	Hithamani and Srinivasan (2014) [29]
9.	Fresh corn	Cooking	1.2-1.9 times increase	Song *et al.* (2013) [76]
10.	Frozen corn	Cooking	47-80% decrease	Song *et al.* (2013) [76]
11.	Fruits	Jam and Jelly processing	7.2-12.6% recovery of bio-accessible total phenolics	Kamiloglua *et al.* (2015) [37]
12.	Tomatoes	Baking	44% increase	Gahler *et al.* (2003) [21]
13.	Tomato juice	Canning	67% increase	Nagarajan and Hotchkiss (1999) [52]
14.	Tomato paste	Canning	40% decrease	Nagarajan and Hotchkiss (1999) [52]
15.	White cabbage	Microwave heating	44-45% decrease in hydrolysable polyphenols	Faller and Fialho (2009) [17]
16.	Wild blackberries	Freezing	8% decrease on wet weight basis	Mullen *et al.* (2002) [51]

Poly-phenolic compounds are water soluble; it is therefore expected that hydrothermal processes has adverse effects on their content (Sikora *et al.*, 2014) [73]. The polyphenol losses could be due to its migration into the leaching solution. Polyphenol losses might be partially explained by the fracture of the outer layer of cells (cell membranes and cells wall) lost during cutting (Kebea *et al.* 2015; Rossi *et al.*, 2003) [38, 67]. In a study conducted by Pradeep and Guha in 2011 [59], it was found that roasting significantly improves the nutraceutical properties of little millet by increasing its content in phenolic compounds and also its antioxidant activities.

According to Ryan and Thondre, 2012 [69] cooking tends to increase the polyphenol release from porridge oats. It increases bio-accessibility of polyphenols. Treatment with pectolytic enzymes resulted in a better extraction of all the fruit components, as polyphenols (about 2 fold) and a decrease of turbidity (−40%) (Rinaldi *et al.*, 2013) [66].

Processing effects on flavonoid content

Table 2: Effect of processing on total flavonoid content

Sr. no.	Raw Ingredient	Processing Method	Changes	References
1.	Beets	Canned without topping juice	30-50% increase on wet weight basis	Jiratanan and Liu (2004) [34]
2.	Cauliflower	Blanched	37.69% decrease	Ahmed and Ali (2013) [2]
3.	Cauliflower	Boiled	51.90% decrease	Ahmed and Ali (2013) [2]
4.	Cauliflower	Microwave heating	18.30% decrease	Ahmed and Ali (2013) [2]
5.	Cauliflower	Steam blanched	16.6% decrease	Ahmed and Ali (2013) [2]
6.	Cauliflower	Steam boiled	17.53% decrease	Ahmed and Ali (2013) [2]
7.	Cauliflower	Stir fried	18.05% decrease	Ahmed and Ali (2013) [2]
8.	Finger millet	Open pan boiling	10% decrease	Hithamani and Srinivasan (2014) [29]
9.	Finger millet	Pressure cooking	68% decrease	Hithamani and Srinivasan (2014) [29]
10.	Finger millet	Sprouting	40% decrease	Hithamani and Srinivasan (2014) [29]
11.	Green beans	Canned with brine	60% decrease on wet weight basis	Jiratanan and Liu (2004) [34]
12.	Little millet	Germination	4.6% increase	Pradeep and Guha (2011) [59]
13.	Little millet	Roasting	25.5% increase	Pradeep and Guha (2011) [59]
14.	Little millet	Steaming	19-22.5% increase	Pradeep and Guha (2011) [59]
15.	Red cabbage	Blanching	43% decrease	Volden *et al.* (2008) [83]
16.	Red cabbage	Boiling	16% decrease	Volden *et al.* (2008) [83]
17.	Red cabbage	Steaming	No significant changes	Volden *et al.* (2008) [83]

Processing effects on Phenolic acids-

The heat and SO_2 treatments of blueberries did not change the content of total phenolic acids (the sum of p-hydroxybenzoic, vanillic, chlorogenic, caffeic, syringic, ferulic and o-coumaric acids) in pressed juice, clarified juice, pasteurized juice and concentrate (Lee *et al.*, 2002). Several researchers reported that the total phenolic content declines due to heat processing but the decline is largely due to leaching into the brine or syrup rather than oxidation (Chaovanalikit, and Wrolstad, 2004; Hong *et al.*, 2004, Zori *et al.*, 2014) [10, 30, 88].

In a study conducted by Quintana *et al.*, 1999 [63] on mushrooms it was found that mushrooms which underwent several washing and immersion steps in addition to thermal processing tends to show maximum loss in total phenolic content during the process of canning. According to Gil-Izquierdo *et al.*, 2002 [25] pasteurization techniques did not influence the total phenolic content of orange juices. Similarly, no effect was reported in these compounds during juice concentration.

Table 3: Effect of processing on total phenolic acids content

Sr. no.	Raw Ingredient	Processing Method	Changes	References
1.	Blue fleshed potatoes	Peeling	80% decrease	Rytela *et al.* (2014) [70]
2.	Fragmented potato	Cooking	70-80% decrease	Takenaca *et al.* (2006) [79]
3.	Fragmented purple fleshed potatoes	Blanching	87% decrease	Burgos *et al.* (2013) [9]
4.	Fragmented yellow fleshed potatoes	Blanching	97% decrease	Mulinacci *et al.* (2008) [50]
5.	Fruits	Jam and jelly processing	49.5- 96.7% decrease	Kamiloglua *et al.* (2015) [37]
6.	Fruits	Jam and jelly processing	4.7- 31.5% increase in bio-accessible phenolic acids	Kamiloglua *et al.* (2015) [37]
7.	Yellow fleshed potatoes	Peeling	60% decrease	Rytela *et al.* (2014) [70]

Potato skins showed much higher amounts of the polyphenols (approximately three and a half times higher) than the potato internal tissue. So, the phenolic acid content decreased by 80% after peeling the blue-fleshed potatoes and by 60% after peeling the yellow variety (Rytela *et al.*, 2014) [70].

Takenaca *et al.* in 2006 [79] proved that cooking fragmented potato in water resulted in the loss of phenolic acids at the level of 70–80%, whereas according to Mulinacci *et al.* (2008) [50] and Burgos *et al.* (2013) [9] cooking the whole unpeeled potatoes did not cause any loss of phenolic compounds. Most of the phenolic groups, sugars, and organic acids showed a better extraction after storage, especially in the slow freezing treatment due to a higher degree of tissue damage by freezing (Veberic *et al.*, 2014) [82].

Processing effects on Flavonols

A loss in flavonol content was observed in several vegetables and fruits during boiling and blanching (Franke *et al.*, 2004) [19].

Both boiling and frying seems to cause considerable losses of quercetin derivatives from broccoli, but fewer were lost upon steaming. Steaming also caused milder losses of quercetin derivatives from carrot than did boiling (Retention Factor = 0.89 and 0.37, respectively). However, losses of quercetin derivatives from onion were similar whether blanched, boiled, fried, or microwaved. Free quercetin content increased upon the blanching and steaming of common cabbage and cauliflower, although this would usually represent only a minor portion of all quercetin derivatives. Carrots were affected similarly by boiling and steaming. In contrast, cauliflower lost almost all quercetin through boiling but retained most through steaming (Rothwell *et al.*, 2015) [68].

Peeling, skinning, trimming, depitting and/or leaf selection may cause a partial or total decrease in flavonol levels (Gennaro *et al.*, 2002) [24]. Onions (*Allium cepa* L.) have been prepared by sautéing, baking and boiling: after baking and sautéing, quercetin concentrations increased by 7–25%, while boiling led to a decrease of 18% in its content (Lombard *et al.*, 2005) [44]. Flavonols, total proanthocyanidins, and hydroxycinnamic acids were well retained in chokeberry juices stored for 6 months at 25 °C (Wilkes *et al.*, 2014; Mogren *et al.*, 2005) [85, 49].

Processing effects on Isoflavones

Each processing step in tofu manufacturing contributes to the loss of isoflavones, resulting in a considerable amount of isoflavones being lost in the resultant by-products. Wang and Murphy observed recovery of total isoflavones in traditional tofu as 33%. Grinding of soaked-soybean in boiling water seems to result in the major loss of isoflavones during processing (Jackson *et al.*, 2002) [33].

Total concentration of isoflavones increased after 1 day of germination and then slowly decreases. This increase and decrease observed in the content of isoflavones may be due to conversion of isoflavones to other flavonoids (Claudio *et al.*, 2010; Kim *et al.*, 2006) [11, 39].

Processing effects on Flavanones

An increase in irradiation dose (400 and 700 Gy) resulted in a decrease in flavanones immediately after irradiation (Patil *et al.*, 2004) [56].

The highest total flavanone levels were found after traditional pasteurization (123– 137 mg/L). The orange juice prepared by freezing had the lowest total flavanone concentration (36 mg/L) (Sanchez-Moreno *et al.*, 2003) [71]. Snchez-Moreno *et al.* in 2005 [75] reported that pulsed electric fields had no influence on flavanone content.

Processing effects on Flavones

The percentage of flavones in the juices obtained manually was always lower than in the juices extracted using industrial methods (Nogata *et al.*, 2003) [53].

Processing effects on Flavanols (Catechins)

Table 4: Effect of processing on catechins content

Sr. no.	Raw Ingredient	Processing Method	Changes	References
1.	Cauliflower	Steam blanching	55.49% decrease	Ahmed and Ali (2013) [2]
2.	Cauliflower	Steam boiling	62.83% decrease	Ahmed and Ali (2013) [2]

Blanching, boiling, microwaving, and stir-frying affect the composition, phytochemical contents, antioxidant activity, and phenolic profiles of cauliflower (Mansour *et al.*, 2015; Ahmed and Ali, 2013) [47, 2]. Processing has profound effect on the level of catechins as a result of epimerization and also due to degradation. It has been reported that even the brewing step could convert epicatechins to their corresponding epimers. These types of conversions continue to take place during the production of canned tea beverages and also during subsequent storage period (Preedy, 2014) [60].

Pasteurization increased the concentration of catechins in cold pressed juices, but it decreased concentrations in hot-pressed juices (Fuleki and Ricardoda Silva, 2002) [20].

Processing effects on Chalcones

Very few applications deal with chalcones or structurally related compounds. Cloudy juice contains more dihydrochalcon glycosides than clear apple juice and freshly home-pressed juice more than commercially produced juice (Amarowicz *et al.*, 2009) [4]. Storage at moderate temperatures produced no considerable changes in the content of glycosides but the use of high temperatures led to its reduction (Kahle *et al.*, 2005; Van der Sluis *et al.*, 2005) [36, 81].

Processing effects on Tannins-

Table 5: Effect of processing on tannin content

Sr. no.	Raw Ingredient	Processing Method	Changes	References
1.	Finger millet	Microwave	31% decrease	Hithamani and Srinivasan (2014) [29]
2.	Finger millet	Open pan boiling	35-75% decrease	Hithamani and Srinivasan (2014) [29]
3.	Finger millet	Pressure cooking	40% decrease	Hithamani and Srinivasan (2014) [29]
4.	Finger millet	Sprouting	30% decrease	Hithamani and Srinivasan (2014) [29]
5.	Little millet extract	Roasting	18.8% increase	Pradeep and Guha (2011) [59]
6.	Pearl millet	Germination	0.28- 0.36% increase	Pradeep and Guha (2011) [59]

In a study conducted by Lowhard *et al.* (2012) [45] it was reported that tannins in blueberries, blackberries and black raspberries are susceptible to degradation during processing, with juices showing the greatest losses due to physical removal of skins and seeds.

Tannin and catechin contents in lentils (*L.cu linaris var. Vulgaris* and *Variabilis*) were also analyzed after 6 days of germination. Germination brought about an increase of tannin content for both varieties (152% and 162% retention percentages were observed, respectively). Catechin content showed an even larger increase, reaching a level twice that of the raw seed (Valverde *et al.*, 1994) [80]. Tannins effectively lowered upon boiling and pressure cooking respectively, but significantly increased upon germination (Pushparaj and Urooj, 2011) [61].

Conclusion

Polyphenol profiles of most of the fruits and vegetables are adversely affected by the commonly used processing methods in our country as blanching, boiling, microwaving, and stir-frying. Steam blanching process generally gives products with less polyphenol losses when compared with simple blanching and time duration of the application is also related with the amount of losses in ultimate product. Peeling showed maximum losses of phenolic content as these contents are more profoundly common in the outer most portions of fruits and vegetables. Some processing methods as germination, roasting increased the bioavailability of certain phenolic compounds. If storage conditions are ambient then the losses of sub-classes of poly-phenolic compounds can be reduced to minimum.

References

1. Abu-Ghannam N, Jaiswal AK. Blanching as a treatment process: Effect on polyphenols and antioxidant capacity of cabbage. In: Preedy V. (Ed.), Processing and impact on active components in food Elsevier/Academic Press, London, UK. 2015, 35-43.
2. Ahmed FA, Ali RFM. Bioactive compounds and antioxidant activity of fresh and processed white cauliflower. BioMed Research International 2013; 20:9.
3. Ahn J, Cho I, Kim S, Kwon D, Ha T. Dietary resveratrol alters lipid metabolism-related gene expression of mice on an at herogenic diet. Journal of Hepatology. 2008; 49:1019-1028. http://dx.doi.org/10.1016/j.jhep.2008.08.012
4. Amarowicz R, Carle R, Dongowski G, Durazzo A, Galensa R, Kammerer D, Maiani G, Mariusz K. Influence of postharvest processing and storage on the content of phenolic acids and flavonoids in foods. Molecular Nutrition and Food Research. 2009; 53:151-183. DOI 10.1002/mnfr.200700486
5. Andlauer W, Stumpf M, Hubert A, Rings A, Fürst P. Influence of cooking process on phenolic marker compounds of vegetables. International Journal for Vitamin and Nutrition Research. 2003; 73:152-159.
6. Arts ICW, Hollman PCH. Polyphenols and disease risk in epidemiologic studies. American Journal of Clinical Nutrition. 2005; 81:317-325.
7. Asami DK, Hong YJ, Barrett DM, Mitchell AE. Processing induced changes in total phenolics and procyanidins in clingstone peaches. Journal of Science, Food and Agriculture. 2002; 83:56-63.
8. Blessington T, Nzaramba MN, Douglas C, Anna SL. Cooking Methods and Storage Treatments of Potato: Effects on Carotenoids, Antioxidant Activity, and Phenolics. American Journal of Potato Research. 2010; 87:479-491. DOI 10.1007/s12230-010-9150-7.
9. Burgos G, Amoros W, Muñoa L, Sosa P, Cayhualla E, Sanchez C. 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. 2013; 30:6-12.
10. Chaovanalikit A, Wrolstad RE. Total anthocyanins and total phenolics of fresh and processed cherries and their antioxidant properties. Journal of Food Science 2004; 69:67-70.
11. Claudio LA, Solange G, Canniatti-Brazaca, Yong KP, Severino M. Effects of the Processing Techniques on Isoflavone Profiles. Nova Science Publishers, 2010; 225-236. Accessed on 4/5/2016
12. Del Rio D, Rodriguez-Mateos A, Spencer JPE, Tognolini M, Borges G, Crozier A. Dietary (poly) phenolics in Human Health: Structures, Bioavailability, and Evidence of Protective Effects against Chronic Diseases. Antioxidants & Redox Signaling 2012; 18:1-73. http://dx.doi.org/10.1089/ars.2012.4581
13. Demrow HS, Slane PR, Folts JD. Administration of wine and grape juice inhibits *in vivo* platelet activity and thrombosis in stenosed canine coronary arteries. Circulation. 1995; 91:1182-1188.
14. Egert S, Boesch-Saadatmandi C, Wolffram S, Rimbach G, Müller MJ. Serum lipid and blood pressure responses to quercetin vary in overweight patients by apolipoprotein e genotype1,2. The Journal of Nutricion 2010; 140:278-284. http://dx.doi.org/10.3945/jn.109.117655
15. Egert S, Bosy-Westphal A, Seiberl J, Kürbitz C, Settler U, Plachta-Danielzik S *et al*. Quercetin reduces systolic blood pressure and plasma oxidized low-density lipoprotein concentrations in overweight subjects with a high-cardiovascular disease risk phenotype: a double-blinded, placebo-controlled cross-over study. British Journal of Nutrition. 2009; 102:1065-1074. http://dx.doi.org/10.1017/S0007114509359127
16. Ejaz A, Wu D, Kwan P, Meydani M. Curcumin inhibits adipogenesis in 3t3-l1 adipocytes and angiogenesis and obesity in C57/bl mice1-3. The Journal of Nutrition and Disease. 2009; 139:919-925. http://dx.doi.org/10.3945/jn.108.100966
17. Faller A, Fialho E. The antioxidant capacity and polyphenol content of organic and conventional retail vegetables after domestic cooking. Food Research International. 2009; 42:210-215.
18. Fouad A, Ahmed, Rehab FM. Bioactive Compounds and Antioxidant Activity of Fresh and Processed White Cauliflower. Hindawi Publishing Corporation BioMed Research International, 2013. Article ID 367819, 9 pages http://dx.doi.org/10.1155/2013/367819
19. Franke AA, Custer LJ, Arakaki C, Murphy SP. Flavonoid levels of fruits and vegetables consumed in Hawaii. Journal of Food Composition Analysis. 2004; 17:1-35.
20. Fuleki T, Ricardoda Silva JM. Effects of Cultivar and Processing Method on the Contents of Catechins and Procyanidins in Grape Juice. Journal of Agricultural Food Chemistry 2002; 51(3):640-646 DOI: 10.1021/jf020689m
21. Gahler S, Otto K, Bohm V. Alterations of vitamin C, total phenolics, and antioxidant capacity as affected by processing tomatoes to different products. Journal of Agricultural Food Chemistry. 2003; 51:7962-7968.
22. García Lafuente A, Guillamón E, Villares A, Rostagno MA, Martínez JA. Flavonoids as anti-inflammatory agents: implications in cancer and cardiovascular disease. Inflammation Research. 2009; 58:537-552.
23. Gee JM, DuPont MS, Rhodes MJ, Johnson IT. Quercetin glucosides interact with the intestinal glucose transport pathway. Free Radical Biology and Medicine. 1998; 25:19-25.
24. Gennaro L, Leonardi C, Esposito F, Salucci M. Flavonoid and carbohydrate contents in tropea red onions: Effects of home like peeling and storage. Journal of Agricultural Food Chemistry. 2002; 50:1904-1910.
25. Gil-Izquierdo A, Gil MI, Ferreres F. Effect of processing techniques at industrial scale on orange juice antioxidant and beneficial health compounds. Journal of Agricultural Food Chemistry. 2002; 50:5107-5114.
26. Gonçalves EM, Pinheiro J, Abreu M, Brandão TRS, Silva CLM. Carrot (*Daucus carota* L.) peroxidase inactivation, phenolic content and physical changes kinetics due to blanching. Journal of Food Engineering. 2010; 97:574-581.
27. Halliwell B. Dietary polyphenols: good, bad, or indifferent for your health? Cardiovascular Research. 2007; 73:341.

28. Harikumar KB, Aggarwal BB. Resveratrol: a multitargeted agent for age associated chronic diseases. Cell Cycle. 2008; 7:1020-1035.
29. Hithamani G, Srinivasan K. Effect of domestic processing on the polyphenol content and bioaccessibility in finger millet (*Eleusine coracana*) and pearl millet (*Pennisetum glaucum*). Food Chemistry. 2014; 164:55-62.
30. Hong YJ, Barrett DM, Mitchell AE. Liquid chromatography/ mass spectrometry investigation of the impact of thermal processing and storage on peach procyanidins. Journal of Agricultural Food Chemistry. 2004; 52:2366-2371.
31. Ismail A, Marjan ZM, Foong CW. Total antioxidant activity and phenolic content in selected vegetables. Food Chemistry. 2004; 87:581-586.
32. Jaiswal AK, Gupta S, Abu-Ghannam N. Kinetic evaluation of colour, texture, polyphenols and antioxidant capacity of Irish York cabbage after blanching treatment. Food Chemistry. 2012; 131:63-72.
33. Jackson CJC, Dini JP, Lavandier C, Rupasinghe HPV, Faulkner H, Poysa V *et al*. Effects of processing on the content and composition of isoflavones during manufacturing of soy beverage and tofu. Process Biochemistry. 2002; 37:1117-1123.
34. Jiratanan T, Liu RH. Antioxidant activity of processed table beets (Beta vulgaris var. conditiva) and green beans (*Phaseolus vulgaris* L.). Journal of Agricultural Food Chemistry. 2004; 52:2659-2670.
35. Johnson MC, Thomas AL, Greenlief CM. Impact of Frozen Storage on the Anthocyanin and Polyphenol Contents of American Elderberry Fruit Juice. Journal of Agricultural Food Chemistry. 2015; 63(23):5653-5659 DOI: 10.1021/acs.jafc.5b01702
36. Kahle K, Kraus M, Richling E. Polyphenol profiles of apple juices. Molecular Nutrition and Food Research. 2005; 49:797-806.
37. Kamiloglua S, Paslia AA, Ozcelika B, Campb JV, Capanoglua E. Influence of different processing and storage conditions on *in vitro* bioaccessibility of polyphenols in black carrot jams and marmalades. Food Chemistry. 2015; 186:74-82.
38. Kebea M, Renarda CMCG, El Maâtaouic M, Amanid GNG, Maingonnata JF. Leaching of polyphenols from apple parenchyma tissue as influenced by thermal treatments. Journal of Food Engineering. 2015; 166: 237-246.
39. Kim EH, Kim SH, Chung JI, Chi HY. Analysis of phenolic compounds and isoflavones in soybean seeds (*Glycine max L. Merill*) and sprouts grown under different conditions. European Food Research and Technology. 2006; 222:201-208.
40. King A, Young G. Characteristics and Occurrence of Phenolic Phytochemicals. Journal of the American Dietetic Association 1999; 99:213-218. http://dx.doi.org/10.1016/S0002-8223(99)00051-6
41. Lee J, Durst RW, Wrolstad RE. Impact of juice processing on blueberry anthocyanins and polyphenolics: Comparison of two pretreatments. Journal of Food Science. 2002; 67:1660-1667.
42. Li RW, Douglas TD, Maiyoh GK, Adeli K, Theriault AG. Green tea leaf extract improves lipid and glucose homeostasis in a fructose-fed insulin-resistant hamster model. Journal of Ethnopharmacology. 2006; 104:24-31.
43. Lima GPP, Vianello F, Corrêa CR, da Silva Campos RA, Borguini MG. Polyphenols in fruits and vegetables and its effect on human health. Food and Nutrition Sciences 2014; 5:1065-1082. http://dx.doi.org/10.4236/fns.2014.511117
44. Lombard K, Peffley E, Geoffriau E, Thompson L, Herring A. Quercetin in onion (*Allium cepa* L.) after heat-treatment simulating home preparation. Journal of Food Composition Analysis. 2005; 18:571-581.
45. Lowhard LR, Prior RL, Liyanage R, Lay JO. Processing and Storage Effect on Berry Polyphenols: Challenges and Implications for Bioactive Properties. Journal of Agricultural Food Chemistry. 2012; 60(27):6678-6693 DOI: 10.1021/jf2046575
46. Luqman S, Rizvi SI. Protection of lipid peroxidation and carbonyl formation in proteins by capsaicin in human erythrocytes subjected to oxidative stress. Phytotherapy Research. 2006; 20:303-306.
47. Mansour AA, Elshimy NN, Shekib LA, Sharara MS. Effect of Domestic Processing Methods on the Chemical Composition and Organoleptic Properties of Broccoli and Cauliflower. American Journal of Food and Nutrition. 2015; 3(5):125-130. doi: 10.12691/ajfn-3-5-3.
48. Ming H. Commentary: bioavailability of flavonoids and polyphenols: call to arms. Molecular Pharmaceutics. 2007; 4(6):803.
49. Mogren L, Gertsson U, Olsson M. Postharvest aspects on bioactive compounds in yellow onion (*Allium cepa*), Acta Horticulturae. 2005; 682:535-536.
50. Mulinacci N, Ieri F, Giaccherini C, Innocenti M, Andrenelli L, Canova G. Effect of cooking on the anthocyanins, phenolic acids, glycoalkaloids, and resistant starch content in two pigmented cultivars of *Solanum tuberosum* L. Journal of Agriculture and Food Chemistry. 2008; 56:11830-11837.
51. Mullen W, Stewart AJ, Lean MEJ, Gardner P, Duthie GG, Crozier A. Effect of Freezing and Storage on the Phenolics, Ellagitannins, Flavonoids, and Antioxidant Capacity of Red Raspberries. Journal of Agriculture and Food Chemistry. 2002; 50:5197-5201.
52. Nagarajan N, Hotchkiss JH. *In vitro* inhibition of N nitrosomorpholine formation by fresh and processed tomatoes. Journal of Food Science. 1999; 64:964-967.
53. Nogata Y, Ohta H, Sumida T, Sekiya K. Effect of extraction method on the concentrations of selected bioactive compounds in mandarin juice. Journal of Agriculture and Food Chemistry. 2003; 51:7346-7351.
54. Pandey KB, Mishra N, Rizvi SI. Protective role of myricetin on markers of oxidative stress in human erythrocytes subjected to oxidative stress. Natural Product Communication. 2009; 4:221-226.
55. Pandey KB, Rizvi SI. Plant polyphenols as dietary antioxidants in human health and disease. Oxidative Medicine and Cellular Longevity. 2009; 2(5):270-278.
56. Patil BS, Vanamalaa J, Hallmanc G. Irradiation and storage influence on bioactive components and quality of early and late season, Rio Red' grapefruit (*Citrus paradise Macf.*), Postharvest Biology Technology. 2004; 34:53-64.
57. Podsedek A, Sosnowska D, Redzynia M, Koziołkiewicz M. Effect of domestic cooking on the red cabbage hydrophilic antioxidants. International Journal of Food Science and Technology. 2008; 43:1770-1777.
58. Potenza MA, Marasciulo FL, Tarquinio M, Tiravanti E, Colantuono G, Federici A. EGCG, a green tea

polyphenol, improves endothelial function and insulin sensitivity, reduces blood pressure, and protects against myocardial i/r injury in SHR. American Journal of Physiology, Endocrinology and Metabolism. 2007; 292:1378-1387. http://dx.doi.org/10.1152/ajpendo.00698.2006
59. Pradeep SR, Guha M. Effect of processing methods on the nutraceutical and antioxidant properties of little millet (*Panicum sumatrense*) extracts. Food Chemistry. 2011; 126:1643-1647.
60. Preedy VR. Processing and Impact on Antioxidants in Beverages. Kidlington, Oxford, UK: Academic Press, 2014, 100.
61. Pushparaj FS, Urooj A. Influence of Processing on Dietary Fiber, Tannin and *in vitro* Protein Digestibility of Pearl Millet. Food and Nutrition Sciences. 2011; 2:895-900 doi:10.4236/fns.2011.28122
62. Puupponen-Pimi RH, Akkinen ST, Aarni M, Suortti T, Lampi AM, Eurola M. Blanching and long-term freezing affect various bioactive compounds of vegetables in different ways. Journal of the Science of Food and Agriculture. 2003; 83:1389-1402.
63. Quintana VAM, Gonz´alez-San Jos´e ML, Collada-Fern´andez M. Influence of canning process on colour, weight and grade of mushrooms. Food Chemistry. 1999; 66:87-92.
64. Ramos S. Effects of dietary flavonoids on apoptotic pathways related to cancer chemoprevention. Journal of Nutritional Biochemistry. 2007; 18:427.
65. Rickman JC, Barrett DM, Bruhn CM. Nutritional comparison of fresh, frozen and canned fruits and vegetables. Part 1. Vitamins C and B and phenolic compounds. Journal of the Science of Food and Agriculture. 2007; 87:930-944.
66. Rinaldi M, Caligiani A, Borgese R, Palla G, Barbanti D, Massini D *et al*. The effect of fruit processing and enzymatic treatments on pomegranate juice composition, antioxidant activity and polyphenols content. LWT Food Science and Technology. 2013; 53(1):355-359.
67. Rossi M, Giussani E, Morelli R, Scalzo R. Effect of fruit blanching on phenolics and radical scavenging activity of high bush blueberry juice. Food Research International. 2003; 36:999-1005.
68. Rothwell JA, Remo AM, Jime JP, Neveu V, Knaze V, Slimani N *et al*. Effects of food processing on polyphenol contents: A systematic analysis using Phenol-Explorer data. Molecular Nutrition and Food Research. 2015; 59:160-170.
69. Ryan L, Thondre PS. Effect of cooking on polyphenol bioaccessibility and digestibility of porridge oats. Summer Meeting hosted by the Irish Section, 16–19 July 2012, Translational nutrition: integrating research, practice and policy. Proceedings of the Nutrition Society 2012; 71 (OCE2), E131 doi:10.1017/S0029665112001887
70. Rytela E, Czopeka AT, Kitaa A, Aniołowskaa M, Kucharskab AZ, Sokół Łętowskab A *et al*. Content of polyphenols in coloured and yellow fleshed potatoes during dices processing. Food Chemistry 2014; 161:224–229
71. Sanchez-Moreno C, Plaza L, Ancos B, Cano MP. Quantitative bioactive compounds assessment and their relative contribution to the antioxidant capacity of commercial orange juices. Journal of the Science of Food and Agriculture. 2003; 83:430-439.
72. Scalbert A, Manach C, Morand C, Remesy C. Dietary polyphenols and the prevention of diseases. Critical Review in Food Science and Nutrition. 2005; 45:287-306. http://dx.doi.org/10.1016/j.jep.2005.08.045
73. Sikora E, Borczakin B. Hydrothermal Processing on Phenols and Polyphenols in Vegetables Polyphenols in Plants: Isolation, Purification and Extract Preparation-chapter 2014; 13:241-257.
74. Singh M, Arseneault M, Sanderson T, Murthy V, Ramassamy C. Challenges for research on polyphenols from foods in Alzheimer's disease: Bioavailability, metabolism, and cellular and molecular mechanisms. Journal of Agriculture and Food Chemistry. 2008; 56:4855-4873.
75. Snchez-Moreno C, Plaza L, Elez-Mart nez P, Ancos B. Impact of high pressure and pulsed electric fields on bioactive compounds and antioxidant activity of orange juice in comparison with traditional thermal processing. Journal of Agriculture and Food Chemistry. 2005; 53:4403-4409.
76. Song JF, Liu CQ, Li DJ, Meng LL. Effect of cooking methods on total phenolic and carotenoid amounts and DPPH radical scavenging activity of fresh and frozen sweet corn (*Zea mays*) kernels. Czech Journal of Food Sciences. 2013; 31:607-612.
77. Spencer JP, Abd El, Mohsen MM, Minihane AM, Mathers JC. Biomarkers of the intake of dietary polyphenols: Strengths, limitations and application in nutrition research. British Journal of Nutrition. 2008; 99:12-22.
78. Szkudelska K, Nogowski L, Szkudelski T. Resveratrol, a naturally occurring di-phenolic compound, affects lipogenesis, lipolysis and the anti-lipolytic action of insulin in isolated rat adipocytes. The Journal of Steroid Biochemistry and Molecular Biology. 2009; 113:17-24. http://dx.doi.org/10.1016/j.jsbmb.2008.11.001
79. Takenaca M, Nanayama K, Isobe S, Murata M. Changes in caffeic acid derivatives in sweet potato (*Impomoea batata* L.) during cooking and processing. Bioscience, Biotechnology and Biochemistry. 2006; 70:172-177.
80. Valverde CV, Estrella JFI, Ruiz MJGR, Bacon J. Effect of Processing on Some Antinutritional Factors of Lentils. Journal of Agriculture and Food Chemistry. 1994; 42:2291-2295.
81. Van der Sluis AA, Dekker M, Van Boekel MAJS. Activity and concentration of polyphenolic antioxidants in apple juice. 3. Stability during storage. Journal of Agriculture and Food Chemistry 2005; 53:1073-1080.
82. Veberic R, Stampar F, Schmitzer V, Cunja V, Zupan A, Koron D *et al*. Changes in the Contents of Anthocyanins and Other Compounds in Blackberry Fruits Due to Freezing and Long Term Frozen Storage. Journal of Agriculture and Food Chemistry. 2014; 62(29):6926-6935.
83. Volden J, Borge GIA, Bengtsson GB, Hansen M, Thygesen IE, Wicklund T. Effect of thermal treatment on glucosinolates and antioxidant-related parameters in red cabbage (*Brassica oleracea L. ssp. capitata f. rubra*). Food Chemistry. 2008; 109:595-605.
84. Wang HJ, Murph PA. Mass balance study of isoflavones during soybean processing. Journal of Agriculture and Food Chemistry. 1996; 44:2377-83.
85. Wilkes K, Howard LR, Brownmiller C, Prior RL. Changes in Chokeberry (*Aronia melanocarpa* L.) Polyphenols during Juice Processing and Storage. Journal

of Agriculture and Food Chemistry. 2014; 62(18):4018-4025.

86. Young JF, Nielsen SE, Haraldsdóttir J, Daneshvar B, Lauridsen ST, Knuthsen P *et al*. Effect of fruit juice intake on urinary quercetin excretion and biomarkers of anti-oxidative status. American Journal of Clinical Nutrition. 1999; 69:87-94.
87. Zhang D, Hamauzu Y. Phenolics, ascorbic acid, carotenoids and antioxidant activity of broccoli and their changes during conventional and microwave cooking. Food Chemistry. 2004; 88:503-509.
88. Zori Z, Dragovi-Uzelac V, Pedisi S. Kinetics of the degradation of anthocyanins, phenolic acids and flavonols during heat treatments of freeze-dried sour cherry marasca paste. Food Technology and Biotechnology. 2014; 52(1):101-108.