The review of literature of the study titled ‘Total antioxidant capacity of commonly consumed Indian foods and plasma antioxidant status of Indian adults’ is discussed under the following heads

A. Antioxidants in health and disease

B. Antioxidant assays

C. Antioxidants in foods

D. Total antioxidant capacity

E. Food intake on plasma antioxidant capacity

A. **Antioxidants in health and disease**

The role of antioxidants in health and disease has been and is being extensively studied. The balance between antioxidant intake and production of free radicals in the body has been deduced as a preventive measure in the onset of degenerative diseases. On the reverse, diseases also increase the oxidative stress in the body. The overproduction of ROS along with lack of antioxidant defense promote oxidative damage and is involved in the etiology of various degenerative diseases (Valko et al., 2005; Gupta et al., 2007; Ulrich-Merzenich et al., 2009) and this has an influence on plasma antioxidant capacity (Buico et al., 2009). The consumption of antioxidant rich foods have been shown to have a positive effect in health, oxidative stress and disease.

**Elderly and Aging**

An intervention study performed on 320 elderly subjects (Galan et al., 2006) following a program to maintain physical activity and reduce Cardio Vascular Disease (CVD) risk by asking them to do regular exercise concurrent with a
nutritional antioxidant treatment. Sustained exercise (10 months, 3 sessions/week) significantly increased cardiorespiratory fitness and plasma HDL-cholesterol; it reduced some predictors of cardiovascular risk (arterial pressure, LDL-cholesterol, total cholesterol/LDL-C, LDL-C/HDL-C), but significantly enhanced some biomarkers of oxidative stress. Concurrent antioxidant supplementation did not produce any ergogenic effects, but meaningfully, enhanced some positive effects of exercise on physical health and the CVD risk index, and it totally prevented the exercise-induced oxidative stress. The results of the study show that regular and moderate exercise improves cardiorespiratory function and reduces CVD risk in elderly people, while concurrent antioxidant supplementation modulates oxidative insult during exercise in the elderly and enhances the beneficial effects of exercise.

**Cardiovascular disease**

Reviewing the antioxidant hypothesis that suboptimal levels of principal antioxidant micronutrients are hitherto underrated risk factors for cardiovascular diseases, Gey, 1995, says that the complementary observational data consistently suggest optimal, i.e., potentially protective plasma levels of approximately >50 μmol/L of vitamin C, >30 μmol/L of lipid-standardized vitamin E (α-tocopherol/cholesterol ratio >5.2 μmol/mmol) and >0.4 μmol/L β (>0.5 μmol/L total)-carotene. Relative risks are doubled at >25 to 50 percent lower values.

The associations linking endothelial inflammation, endothelial oxidative stress, and atherogenesis and the potential for dietary phytonutrients to decrease the impact of these associations were assessed. A detailed literature review was conducted by Riccioni et al., 2012. They have reported a large body of scientific evidence describing the interactions among endothelial inflammation, endothelial oxidative stress, and atherogenesis. Several dietary phytonutrients (astaxanthin, lycopene, lutein, and glabridin) can decrease the risk for atherosclerosis by decreasing endothelial inflammation and oxidative stress. The consumption of foods or dietary supplements that provide astaxanthin, lycopene, lutein, and glabridin can ameliorate endothelial inflammation and oxidative stress, retard atherogenesis and decrease the risk of atherogenic cardiovascular disease.
Diabetes mellitus

According to Okubo et al., (2013), dietary antioxidants may play a protective role in the aetiology of type II diabetes. They examined the relationships between dietary total antioxidant capacity and markers of glucose metabolism among 1441 men and 1253 women aged 59–73 years who participated in the Hertfordshire Cohort Study, UK. They observed that in men, dietary TAC was inversely associated with fasting insulin concentration and homoeostasis model assessment of insulin resistance (HOMA-IR), dietary TAC was also inversely related to 120-min glucose concentration. There were no associations with fasting glucose or 120-min insulin concentrations. In women, dietary TAC showed consistent inverse associations with fasting and 120-min glucose and insulin concentrations and HOMA-IR. These associations were more marked among women with BMI ≥30 kg/m². These findings suggest dietary TAC may have important protective effects on glucose tolerance, especially in older obese women.

Oxidative stress

In researching the effects of polyphenol antioxidants on exercise induced oxidative stress, Morillas-Ruiz et al., 2006, observed that under strenuous trial cyclists consuming supplements containing 2.3g of polyphenols per trial had decreased protein oxidation and smaller increase in creatinine kinase and lipid oxidation than the placebo group.

In discussing the role of polyphenols in cellular response and preventive pathogenesis, Virgilli and Marino (2008) present the direct interaction of polyphenols with nuclear receptors and their ability to modulate the activity of key enzymes involved in cell signalling and antioxidant responses

Analysing the biochemical mechanisms of intracellular antioxidants, Chaudiere and Ferrari-Iliou (1999), report that apart from enzymes, ascorbates, glutathione and ergothionene act as hydrophilic scavengers and α-tocopherol, carotenoids act as hydrophilic scavengers.
The antioxidant activity of six natural isolated chlorophyll derivatives by measuring their protective action against lipid oxidation was investigated by Lanfer-Marquez et al., (2005). They observed that the natural compound displayed measurable antioxidant activity, the highest by pheophorbide b. They suggest that the mechanism of the antioxidant activity displayed by the natural derivatives is by protection of linoleic acid against oxidation and/or preventing decomposition of hydroperoxides.

Considering the role of Reactive Oxygen Species (ROS) in smoking induced lung disease, Rahman and MacNee (1996), have received the evidence for the presence of an oxidant/antioxidant imbalance in smoking induced lung disease and its relevance to therapy in these conditions.

Antioxidants play a protective role against the state of high oxidative stress during gestation. A study was designed by McLernon et al., 2012, to characterize the circulating profile of tocopherols and carotenoids in pregnant women in asthma and to determine whether asthma severity and dietary intake were associated with an altered antioxidant profile. Pregnant women with moderate/severe asthma were found to have increased concentrations of carotenoids, lutein and α-tocopherol. Their findings suggest that the maternal system adjusts antioxidant pathways in response to the presence of a high oxidative load induced by asthma during pregnancy in an attempt to ensure continued fetal growth in an adverse environment.

The decrease in the bioavailability of nitric oxide caused by oxidative stress is highly associated with endothelial dysfunction, being one of the contributory factors for appearance and development of cardio vascular disease. Frombaum et al., (2012) place that resveratrol and some stilbene derivatives have the capacity to maintain sufficient nitric oxide bioavailability in the vascular endothelium.

In studying the effect of coenzyme Q10 supplementation on oxidative stress and antioxidant enzyme activity in patients with Coronary Artery Disease(CAD), Lee et al., (2012) have observed that coenzyme Q10 supplement at a dose of 150mg can decrease oxidative stress and increase antioxidant enzyme activity in
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patients with CAD. A higher dose of coenzyme Q10 supplement (>150mg/day) might promote rapid and sustainable antioxidation in patients with CAD.

Yardim-Akaydin et al., (2003), investigated the plasma homocysteine, cysteine, vitamin E, C and A and beta carotene (BC) levels in cardiovascular patients and also the possible correlation between the plasma thiol compounds and antioxidant vitamins. They observed that plasma homocysteine and cysteine levels were significantly higher in patients than in controls and the vitamin C, A and BC levels were lower in patients than controls. Also, the plasma level of homocysteine was significantly negatively correlated with vitamin E and A levels. Plasma cysteine levels were negatively correlated with only vitamin C levels.

Spark et al., (2002), observed that the total antioxidant capacity is significantly reduced in patients with chronic critical limb ischemia and this may, in part, be explained by their impaired nutritional status.

In investigating the changes in 8-hydroxy-deoxyguanosine, nitrate, total glutathione, total antioxidant capacity levels and superoxide dismutase, catalase, glutathione peroxidase activities in operative patients with gastrointestinal cancer before and after surgery and comparing the parameters with inoperative patients, Gonenc et al., 2012, observed that the oxidant/antioxidant balance was altered in favor of free radicals and DNA damage in gastrointestinal cancer patients. Significant increases in 8-hydroxy-deoxyguanosine, glutathione and decreases in nitrite + nitrate, SOD, CAT activities and antioxidant molecules suggest the possible involvement of oxidative stress in gastrointestinal cancer. Glutathione peroxidise activities in post operative patients were higher compared with inoperative patients.

B. Antioxidant assays

The antioxidant capacity of natural products has been measured by a variety of methods and is determined by several factors and thus it should be mentioned which factor is being measured by the method employed. There is no universal method that can measure the antioxidant capacity very accurately and quantitatively because the antioxidant activity estimation is highly affected by the
ROS or the Reactive Nitrogen Species (RNS) employed in the assay, even though the chemical structure of the selected antioxidant molecule primarily determines its antioxidant capacity. It is thus important to employ multiple antioxidant assays to characterize the nature of the selected antioxidant preparation (Charles, 2013).

Badarinath et al., (2010), opine that factors affecting oxidation reactions and antioxidant activities in foods and in vitro differ. The current approaches have still left many open questions. In vitro assays can only rank antioxidant activity for their particular reaction system and their relevance to in vivo health protective activities is uncertain. Therefore, it is prudent to use more than one type of antioxidant assay to measure antioxidant activities, and to include at least one assay that has biological relevance. In comparing various methods they suggest that ORAC (Oxygen Radical Absorbance Capacity), TRAP (Total radical trapping antioxidant parameter) and ECL (Enhanced chemi luminescence) have high biological relevance.

It is proposed that three of the methods, namely, ORAC, Folin-Ciocalteau phenolics assay, and TEAC (Trolox equivalent antioxidant capacity) should be standardized for use in the routine quality control and measurement of antioxidant capacity of dietary supplements and other botanicals but other standard assays developed based on radicals used in the essay need to be considered (Prior et al., 2005).

When comparing different assays, the 2,2′-azinobis-(3-ethylbenzothiazoline-6-sulfonic acid (ABTS), Ferric reducing antioxidant power assay (FRAP), 2,2′-diphenyl-1-picrylhydrazyl (DPPH) assay and ORAC assays gave comparable results for the antioxidant activity measured in methanol extract of guava fruit extracts. The FRAP technique showed high reproducibility, was simple, rapidly performed and showed the highest correlation with both ascorbic acid and total phenolics. Therefore, it would be an appropriate technique for determining antioxidant capacity (Thaiponga et al., 2006).

Sultana et al., (2009), investigated the effects of four extracting solvents [absolute ethanol, absolute methanol, aqueous ethanol (ethanol: water, 80:20 v/v)
and aqueous methanol (methanol: water, 80:20 v/v)] and two extraction techniques (shaking and reflux) on the antioxidant activity of extracts of barks of *Azadirachta indica*, *Acacia nilotica*, *Eugenia jambolana*, *Terminalia arjuna*, leaves and roots of *Moringa oleifera*, fruit of *Ficus religiosa*, and leaves of *Aloe barbadensis* were investigated. Generally higher extract yields, phenolic contents and plant material antioxidant activity were obtained using aqueous organic solvents, as compared to the respective absolute organic solvents. Although higher extract yields were obtained by the refluxing extraction technique, in general higher amounts of total phenolic contents and better antioxidant activity were found in the extracts prepared using a shaker.

The effects of four extracting solvents, that is, ethanol, methanol, n-Hexane and pet ether and two extraction techniques that is, simple maceration and hot percolation (Soxhlet apparatus) were investigated by Khan *et al.*, (2012), on the antioxidant activity of pods, leaves, barks and flowers of Cassia fistula. 1,1-diphenyl-2-picryl-hydrazyl (DPPH) was used as standard freeradical while ascorbic acid (Vitamin C) and Quercetin were used as standard antioxidants. Experiments revealed that extracts have solvent-dependent and technique-dependent antioxidant effects. Using the simple maceration technique, 70 percent methanolic v/v leaf extract showed 89 percent DPPH scavenging activity when ascorbic acid was taken as standard and 84.7 percent when quercetin was taken as standard.

In analyzing the antioxidant activity of 100 percent and 80 percent methanol extracts from barley seeds, Anwar *et al.*, (2010), observed that 80 percent methanol extracts had higher antioxidant activity than 100 percent methanol extracts.

Shabir *et al.*, 2011, investigated the antioxidant and antimicrobial activities and phenolic components of different solvent (absolute methanol, absolute ethanol, absolute acetone, 80 percent methanol, 80 percent ethanol, 80 percent acetone and deionized water) extracts of leaves, flowers and bark of Gold Mohar [*Delonix regia* (Bojer ex Hook.) Raf.]. The extract yields from leaves, flowers and
bark ranged from 10.19 to 36.24, 12.97 to 48.47 and 4.22 to 8.48 g/100 g dry weight (DW), respectively. Overall, 80 percent methanol extract produced from the leaves exhibited significantly (P < 0.05) higher antioxidant activity, with high phenolic contents (3.63 g GAE/100 g DW), total flavonoid contents (1.19 g CE/100 g DW), inhibition of peroxidation (85.54 percent), DPPH scavenging capacity (IC50 value 8.89 μg/mL) and reducing power (1.87).

C. Antioxidants in foods

Different kinds of plant based food, parts of plants, seeds and novel food like seaweeds have been analysed for their antioxidant activity. The following reviews present the antioxidant activity and antioxidant compounds identified in many kinds of food.

Cereals, pulses and legumes

The antioxidant activities and total phenolic content of four cereals (buckwheat, wheat germ, barley, and rye) and four legume seeds (lentils, mungo bean, red kidney bean, and soy bean) were determined by Djordevic et al., 2009. The total phenolic content (TPC), determined according to the Folin-Ciocalteu method, for cereal samples varied from 13.2 to 50.7 mg Gallic acid equivalent/g of dried extract, while for legume samples varied from 17.0 to 21.9 mg Gallic acid equivalent/g of dried extract. Antioxidant activities were comparatively assessed by 2,2-diphenyl-1- picrylhydrazyl (DPPH) scavenging capacity, ferric ion-reducing antioxidant power (FRAP) and the thiobarbituric acid (TBA) method. The tested plant extracts showed promising antioxidant and free radical scavenging activity, thus justifying their traditional use. Among examined cereals all the applied methods, except TBA method, have shown that buckwheat have the highest antioxidant activity, while among examined legumes results varied depending on the method used.

The phenolic acid composition and scavenging capacity against DPPH and ABTS radicals and inhibition of human Low Density Lipoprotein (LDL) oxidation invitro was investigated by Gamel and Abdel-Aal, 2012 and they observed that ferulic acid and p-coumaric acid were the primary phenolic fractions in the whole
grain and pearled fraction accounting for 43-97 percent and 2-55 percent of the total phenolic acids respectively. The outer layers showed high scavenging activity than the endosperm fractions.

Green lentil (Lens culinaris) has been found to have antioxidant activity by Amarowicz et al., 2010. After extraction and fractionation twenty compounds were identified. Catechin and epicatechin glucosides, procyanidin dimmers, quercetin diglycoside and trans-p-coumaric acid were the dominant phenolics in green lentils.

Deunas et al., (2006), assessed the invitro antioxidant capacity of the seedcoat and cotyledon of legumes in relation to their phenolic content. Two varieties of lentils (Lens ulinaris L.) and two varieties of dark peas (Pisum sativum, L.) were analysed for their antioxidant capacities. They observed huge differences in the antioxidant capacity of the seedcoat and cotyledon in both legumes. The seedcoat in which are located principally phenolic compounds with flavonoid structures, presents higher antioxidant activity than the cotyledons in lentils and peas, showing differences in both species but not very large differences between varieties.

Vegetables and Fruits

Ismail et al., (2004), determined the total antioxidant activity and phenolic content of selected common vegetables which included kale, spinach, swamp cabbage and shallots. Among all vegetables (fresh and thermally treated), shallots showed the highest total antioxidant activity followed by spinach, swamp cabbage, cabbage and kale. Spinach had an exceptionally high total phenolic content. This study also revealed that a one minute thermal treatment significantly decreased the total phenolic content of all vegetables studied.

Antioxidant activity of asparagus, broccoli and their juices was evaluated DPPH, ABTS and β-carotene bleaching assays. Asparagus showed greater antioxidant activity than broccoli. Asparagus juice also had greater antioxidant activity than broccoli juice. Methanol and acetone extracts of asparagus and
broccoli had significantly greater antioxidant activity than their water extracts. Asparagus and broccoli extracts, as well as their juices, showed no significant difference in total phenolics content. However, asparagus contained more flavonoids than broccoli. The antioxidant activity of broccoli and asparagus extracts showed a linear relationship with their flavanoid content (Sun et al., 2007).

Having proved the presence of natural antioxidants in spinach leaves and their biological activity in vitro and in vivo, Bergman et al. (2001) have chemically identified the active fractions. They have demonstrated the presence of both flavonoids and p-coumaric acid mesotartarate derivatives as antioxidant components of the aqueous extract of spinach leaves.

The antioxidant properties and total phenolic contents of methanol, acetone and water extracts of mulberry (Morus indica L.) leaves were examined by Arabshahi-Delouee and Urooj (2007) using various experimental models. Methanolic extracts with the highest amount of total phenolics was the most potent antioxidant in all assays. The antioxidant activity of the extract remained unchanged at 50°C and was maximum at neutral pH. The extract stored at 5°C in the dark was stable for 30 days after which the antioxidant activity decreased. On the basis of these results mulberry leaves were found to serve as a potential source of natural antioxidants due to their marked antioxidant activity.

Lycopene in tomatoes and watermelons have been found to be effective antioxidant compounds and Pinto et al. (2011), have observed that the intake of one to three wedges of 6185 watermelon accession would provide between 6 to 18 mg of lycopene and 0.18 to 0.54 mmol TEAC, which might protect from prostate cancer and other oxidative stress related diseases.

Evaluating the antioxidant capacities and total phenolic contents of 62 fruits Fu et al. (2011) observed that different fruits had diverse antioxidant capacities with very large variation among varieties. Seven fruits namely Chinese date, pomegranate, guava, sweet sop, persimmon, Chinese wampee and plum possessed the highest antioxidant capacities and total phenolic contents and could
be important dietary sources of natural antioxidant for prevention of disease caused by oxidative stress.

In a study on fruit extracts from Thailand, Ongphimai et al., 2013, analysed the soluble and insoluble phenolic acids (SPA and IPA) in selected Thai fruit such as orange, banana, guava and mango using isocratic HPLC-UV method were determined. Results showed that the predominant compounds of all fruit studied were IPA (80.2-99.5 percent). Gallic and hydroxybenzoic acids were identified as major SPA in guava and orange, respectively. Gallic, hydroxybenzoic, vanillic, caffeic, syringic and ferulic acids were identified as major IPA in all fruit samples. Ferulic acid was the dominant IPA in orange and banana extracts (335.8 ± 13.38 and 219.5 ± 18.47 µg/g dry weights, respectively). Whilst, gallic acid was the dominant IPA in mango extract (542.5 ± 6.80 µg/g dry weight) and hydroxybenzoic acid was the dominant IPA in guava extract (50.5 ± 8.12 µg/g dry weight). The antioxidant capacity of all fruit extracts was also evaluated using a Folin-Ciocalteu’s assay and DPPH free radical-scavenging assay. The phenolics in bound form of orange extract contained the highest total phenolic content (2.6 ± 0.02 µg GAE/ml). Its antioxidant capacity was 94.9 percent. Whereas insoluble phenolic content of guava extract had the least antioxidant capacity (22.0 percent).

Berries have been found to show the highest antioxidant capacity. Black raspberries are excellent sources of antioxidants and have ten times more antioxidant capacity than many other fruits and vegetables. In estimating the antioxidant activity in black berries, Gansch et al., 2009, observed that the varieties of black raspberries had high phenolic content which ranged from 489.3 to 875.3 mg GAE/100g among the varieties.

In comparing the antioxidant capacity and polyphenol content of wild and cultivated blueberries, Bunea et al., 2011, observed that the total polyphenols content ranged from 424.84 to 819.12 mg GAE/100 g FW, total flavonoids ranged from 84.33 to 112.5 mg QE/100 g FW and total anthocyanins ranged from 100.58 to 300.02 C3GE/100g FW and the wild varieties had higher values than the cultivated varieties.
In another study on the total antioxidant capacity and phenolic composition of three berry fruits (blueberry, blackberry, and strawberry) cultivated in Nanjing were investigated by Huang et al., 2012. Blueberry, with a TEAC value of 14.98 mmol Trolox/100 g dry weight (DW), exhibited the strongest total antioxidant capacity using both the ABTS and the DPPH methods. Blueberry also had the highest total phenolic content (TPC, 9.44 mg gallic acid/g DW), total flavonoid content (TFC, 36.08 mg rutin/g DW), and total anthocyanidin content (TAC, 24.38 mg catechin/g DW). A preliminary analysis using high performance liquid chromatography (HPLC) showed that the blueberry, blackberry, and strawberry samples tested contained a range of phenolic acids (including gallic acid, protocatechuic acid, \(p\)-hydroxybenzoic acid, vanillic acid, caffeic acid, \(p\)-coumaric acid, ferulic acid, ellagic acid, and cinnamic acid) and various types of flavonoids (flavone: luteolin; flavonols: rutin, myricetin, quercetin, and quercetin; flavanols: gallicatechin, epigallocatechin, catechin, and catechin gallate; anthocyanidins: malvidin-3-galactoside, malvidin-3-glucoside, and cyanidin). In particular, the blueberries had high levels of proanthocyanidins and anthocyanidins, which might be responsible for their strong antioxidant activities. These results indicate a potential market role for berries (especially blueberries) as a functional food ingredient or nutraceutical.

**Spices**

In researching clove oil as a powerful antioxidant source, Gulcin et al., 2010, found that clove oil inhibited 97.3 percent lipid peroxidation of linoleic acid emulsion at 15µg/ml concentration which was higher than standard antioxidant compounds such as butylated hydroxyl anisole (BHA), butylated hydroxytoluene (BHT), \(\alpha\)-tocopherol and trolox.

Investigating the antioxidant capacity and major phenolic compounds of nineteen spices commonly consumed in china, Lu et al., (2011), observed that Galangal exhibited the highest antioxidant capacity associated with the highest total phenolic content. Galangin was identified as the principal phenolic component and the main contributor of the highest antioxidant capacity of
galangal. Spices of the family Rutaceae and Lauraceae possessed very high antioxidant capacity and very high levels of phenolics. Generally, chlorogenic acid and rutin were identified as the dominant phenolic compounds in the spice extracts.

Curcumin is a phenolic compound and a major component of curcuma longa. Ak and Gulcin (2008) determined the antioxidant activity of curcumin and found that it inhibited 97.3 percent lipid peroxidation of linoleic acid emulsion at 15 µg/ml concentration higher than standard antioxidants such as BHT, α-tocopherol, trolox which had inhibition of 99.7, 84.6 and 95.6 percent on peroxidation of linoleic acid emulsion at 45 µg/ml.

Hydrodistilled extracts from basil, laurel, parsley, juniper, aniseed, fennel, cumin, cardamom and ginger were assessed for their total phenol content and antioxidant [iron(iii)] reduction, inhibition of linoleic acid peroxidation and iron chelation. The extracts from basil and laurel possessed the highest antioxidant activities except for iron chelation. Although parsley showed the best performance in the iron chelation assay, it was less effective at retarding the oxidation of linoleic acid. In linoleic acid peroxidation assay, one gram of basil and laurel extracts were effective as 177 and 212 mg of trolox respectively. Thus both extracts are promising alternatives to synthetic substances as food ingredients with antioxidant activity (Hinneburg et al., 2006).

A study characterizing the antioxidant activity and phenolic compounds of traditional Chinese medicinal plants associated with anticancer was done by Cai et al., 2004. The Trolox Equivalent Antioxidant Capacity (TEAC) values and total phenolic content for methanolic extracts of herbs ranged from 46.7 to 17.323 µmol Trolox equivalent / 100g dry weight and from 0.22 to 50.3 g of gallic acid equivalents/100g dry weight respectively. Also phenolic compounds were the dominant antioxidant components in the tested medicinal herbs. The major types of phenolic compounds from the most of the herbs included phenolic acids, flavonoids, tannins, coumarins, lignans, quinines, stilbenes and curcuminoids.
Tsantili et al., 2011, investigated the effects of cultivar, drying and storage conditions on Total Phenolics (TP), Total Flavonoids (TF) and Total Antioxidant Capacity. The TP ranged from 16.2 to 7.9 mgGAE/g dry weight, TF from 7.2 to 3 mg catechin equivalents/g dry weight and TAC (by FRAP method) 132.5 to 58.8 μmol Trolox equivalents/g dry weight. Drying resulted in average loss of 14.2 percent, 4.1 percent and 11.9 percent for TP, TF and TAC respectively with a higher loss after 12 month storage. The decrease in all measured variables was advanced by storage time but prevented by low temperature and packaging in nitrogen atmosphere.

Erkan et al. (2008) observed that rosemary (Rosemariaus officinalis L) extract had a higher antioxidant activity (by DPPH and ABTS radical scavenging assays and Ferric thiocyanate test) than blackseed essential oil (Nigella Sativa, L).

Antioxidants were extracted from Japanese pepper (Zanthoxyllum Piperitium DC) fruit and characterized by Yamazaki et al. (2007). The antioxidant activity of the methanol extract from Japanese pepper fruit was found to be equal to that of α-tocopherol and stable under heat treatment. The main components that gave a significant activity from the methanol extract were identified to be hyperoside and quercitin.

**Novel food**

A study designed by Liu et al., 2011, to evaluate both the antioxidant and free-radical scavenging activities of extract and fractions from corn silk revealed that the N-butanol fraction (BF) demonstrated the highest total phenolic content (164.1 ± 9.7 μg GAE/g) and total flavonoids content (69.4 ± 5.1 μg RE/g), accompanied with the highest antioxidant activity compared to other fractions through all antioxidant assays. Two flavone glycosides showing potent antioxidant activity were isolated from BF and identified, by comparing spectral data with literature values, to be isoorientin-2″-O-α-l-rhamnoside and 3′-methoxymaysin. The two isolated flavone glycosides, particularly isoorientin-2″-O-α-l-rhamnoside, demonstrated significant total antioxidant activity, DPPH radical scavenging activity, reducing power and iron-chelating capacity, with EC50 values of
Results obtained indicated that corn silk extracts can be used potentially as a ready accessible and valuable bioactive source of natural antioxidants.

Kappaphycus alvarezii (Doty) – an edible red seaweed was analysed for its antioxidant activity and phenol content by Suresh Kumar et al. (2008). The phenol content of various extracts of the seaweed ranged from 0.683±0.038 percent. The extracts also had good reducing power and in the linoleic acid system, the ethanol extract proved superior to the synthetic antioxidant Butylated Hydroxy Toluene (BHT). Hence they suggest that the extracts of this seaweed could be considered as a natural antioxidant and may be useful for curing diseases arising from oxidative deterioration.

**Novel antioxidant compounds**

Ramalin (γ-glutamyl-N′-(2-hydroxyphenyl)hydrazide), a novel compound, was isolated from the methanol–water extract of the Antarctic lichen Ramalina terebrata by several chromatographic methods. The molecular structure of ramalin was determined by spectroscopic analysis. The experimental data showed that ramalin was five times more potent than commercial butylated hydroxyanisole (BHA) in scavenging 1-diphenyl-2-picryl-hydrazil (DPPH) free radicals, 27 times more potent in scavenging 2,2′-azino-bis (3-ethylbenzthiazoline-6-sulfonic acid free radicals (ABTS⁺) than the vitamin E analogue, trolox, and 2.5 times more potent than BHT in reducing Fe³⁺ to Fe²⁺ ions. Similarly, ramalin was 1.2 times more potent than ascorbic acid in scavenging superoxide radicals and 1.25 times more potent than commercial kojic acid in inhibiting tyrosinase enzyme activity, which ultimately leads to whitening of skin cells. Ramalin showed no or very little cytotoxicity in human keratinocyte and fibroblast cells at its antioxidant concentration. Furthermore, ramalin was assessed to determine its antioxidant activity in vivo. One microgram per milliliter ramalin significantly reduced the released nitric oxide (NO) and 0.125 µg/ml ramalin reduced the produced hydrogen peroxide (H₂O₂) in LPS (lipopolysaccharide)-stimulated murine macrophage Raw 264.7 cells (Paudel et al., 2011)
D. Total antioxidant capacity of diet

In investigating the association of dietary total antioxidant capacity and metabolic syndrome components (adults having at least three of the metabolic syndromes such as hyperglycemia, hypertriglyceridemia, low HDL-C, hypertension and abdominal obesity were selected for the study), Bahadoran et al. (2012) observed that higher dietary antioxidant intakes have favourable effects on metabolic disorders and prevented subsequent weight and abdominal fat gain during a three year follow-up.

Oxidative stress has been advocated as a major cause for cardiovascular disease, and low plasma antioxidant concentrations are associated with endothelial dysfunction, the first step towards atherosclerosis. In a crossover trial, 24 subjects (13 women, mean age 61 ± 3 years), received, in a randomised order, a 14-day high and a 14-day low antioxidant diets, with a 2-week wash-out in between. Both diets were comparable in daily portions of fruits and vegetables, and in alcohol, fibre and macronutrient intake, but differed in their total antioxidant capacity. Before and after each diet, anthropometrics, blood pressure, fasting plasma glucose, lipid profile, hepatic enzymes, circulating antioxidant concentrations, high sensitivity C-reactive protein (hs-CRP) and FMD were assessed. FMD increased significantly during the HT diet compared to the LT (p < 0.000). FMD values were 2.3 percent higher after HT compared with LT (p < 0.001) after adjustment for age, gender and diet order. α-tocopherol increased significantly (p < 0.05) and hs-CRP and of γ-glutamyltranspeptidase decreased significantly (P<0.005 and P<0.00 respectively) during the HT diet when compared with the LT diet. (Franzini et al., 2012).

Antioxidant-rich foods may favorably influence lung function. Giuseppe et al. (2012) examined the possible associations between the total dietary antioxidant capacity (TAC) and pulmonary function in a healthy Italian population. TAC was measured in foods by three different assays and the ferric reducing-antioxidant power (FRAP) assay was selected as the better indicator of dietary TAC. The European Investigation into Cancer and Nutrition Food Frequency Questionnaire was used for dietary assessment. The association between...
quintiles of dietary FRAP and pulmonary indexes were assessed using analysis of variance separately for men and women. They have concluded that dietary TAC may have a favorable role in respiratory health, particularly in premenopausal / never smoker women.

In a randomized control trial to evaluate the intake and status of antioxidants in chronic kidney disease (CKD) patients, Sahni et al., 2012, observed that the diet was significantly lower in antioxidant-rich food intake in all the CKD patients as compared with the healthy controls. The oxidative stress measured in blood was found to be in consonance with the intake from diet. Micronutrients play a major role in the antioxidant status of the patients and must be monitored, as deficiency of these might elevate the oxidative stress of the body especially in chronic diseases.

E. Food Intake and Plasma Antioxidant Capacity

The intake of antioxidant rich foods influences the plasma antioxidant capacity.

Ruel et al., 2005, investigated the effect of flavonoid-rich cranberry juice supplementation on plasma lipoprotein levels and LDL oxidation. For that purpose, 21 men (age ± SD, 38 ± 8 years) were enrolled in a 14-day intervention and instructed to drink cranberry juice 7 mL/kg body weight per day. Physical and metabolic measures including plasma lipid and oxidized LDL (OxLDL) concentrations as well as antioxidant capacity were performed before and after the intervention. At baseline, we found that plasma OxLDL levels were significantly associated with waist circumference ($r = 0.47, P = .0296$) as well as plasma triglyceride ($r = 0.68, P = .0007$) and apolipoprotein B ($r = 0.91, P < .0001$) concentrations. The intervention led to a reduction in plasma OxLDL levels ($-9.9\text{percent} ± 17.8\text{percent}, P = .0131$) and increase in antioxidant capacity ($+6.5\text{percent} ± 10.3\text{percent}, P = .0140$). However, no relationship was found between both of these changes ($r = -.01$, not significant). The intervention did not result in any improvement of plasma lipoprotein-lipid or inflammatory marker concentrations. Our results show that short-term cranberry juice supplementation
is associated with significant increase in plasma antioxidant capacity and reduction in circulating OxLDL concentrations.

The association between \textit{in vitro} antioxidant capacity of dark chocolates with different cocoa percentage and the \textit{in vivo} response on antioxidant status was investigated by Lettieri-Barbato \textit{et al.} (2012). In a randomized crossover design, 15 healthy volunteer consumed 100 g of high antioxidants dark chocolate (HADC) or dark chocolate (DC). \textit{In vitro}, HADC displayed a higher Total Antioxidant Capacity (TAC) than DC. \textit{In vivo}, plasma TAC significantly peaked 2 h after ingestion of both chocolates. TAC levels went back to zero 5 h after DC ingestion whilst levels remained significantly higher for HADC. HADC induced a significantly higher urinary TAC in the 5–12 h interval time than DC. No change was detected in urinary excretion of F2-isoprostanes. Plasma thiols and triacylglycerol levels significantly increased for both chocolate with a peak at 2 h remaining significantly higher for DC after 5 h respect to HADC. Results provide evidence of a direct association between antioxidant content of chocolate and the extent of \textit{invivo} response on plasma antioxidant capacity.

Oxidative stress, caused by an imbalance between antioxidant capacity and reactive oxygen species, may be an early event in a metabolic cascade elicited by a high glycemic index (GI) diet, ultimately increasing the risk for cardiovascular disease and diabetes. Botero \textit{et al.}, (2009), conducted a feeding study to evaluate the acute effects of low-GI compared with high-GI diets on oxidative stress and cardiovascular disease risk factors. Under fasting conditions, total antioxidant capacity was significantly higher during the low-GI vs. high-GI diet based on total ORAC ($11,736 \pm 668$ vs. $10,381 \pm 612$ µmol Trolox equivalents/l, $P= 0.002$). Area under the postprandial response curve also differed significantly between the two diets for total ORAC. No diet effects were observed for the other variables. Enhancement in plasma total antioxidant capacity occurs within 1 week on a low-GI diet, before changes in other risk factors, raising the possibility that this phenomenon may mediate, at least in part, the previously reported effects of GI on health.
Total antioxidant performance (TAP) measures antioxidant capacities in both hydrophilic and lipophilic compartments of serum and interactions known to exist between them. TAP levels were assessed in a subset of Jackson Heart Study (JHS) participants and to examine associations with dietary and total (diet + supplement) intakes of $\alpha$-tocopherol, $\gamma$-tocopherol (diet only), $\beta$-carotene, vitamin C, fruit, vegetables, and nuts, and serum concentrations of $\alpha$-tocopherol, $\gamma$-tocopherol, and $\beta$-carotene. A cross-sectional analysis of 420 (mean age 61 y; 254 women) African American men and women participated in the Diet and Physical Activity Sub-Study of the JHS in Jackson, Mississippi. In multivariate-adjusted models, Talegawker et al., 2009, observed positive associations between total $\alpha$-tocopherol, total and dietary $\beta$-carotene, and total vitamin C intakes and TAP levels ($P$-trend < 0.05). Positive associations were also observed for vegetable, fruit, and total fruit and vegetable intakes ($P$-trend < 0.05). For serum antioxidant nutrients, $\alpha$-tocopherol but not $\beta$-carotene was associated with serum TAP levels. There were inverse associations for serum $\gamma$-tocopherol and TAP levels. Associations for $\alpha$-tocopherol were seen at intake levels much higher than the current Recommended Dietary Allowance. It may, therefore, be prudent to focus on increasing consumption of fruit, vegetables, nuts, and seeds to increase total antioxidant capacity.

In comparing the effects of medium light roast (MLR) and medium roast (MR) paper-filtered coffee on antioxidant capacity and lipid peroxidation in healthy volunteers, in a randomized crossover study, 20 volunteers consumed $482 \pm 61$ ml/day of MLR or MR for four weeks. Plasma total antioxidant status (TAS), oxygen radical absorbance capacity (ORAC), oxidized LDL and $8$-$epi$-prostaglandin F2$\alpha$, erythrocyte superoxide dismutase (SOD), glutathione peroxidase (GPx), and catalase (CAT) activity were measured at baseline and after the interventions. Compared with baseline, subjects had an increase of 21 and 26 percent in TAS, 13 and 13 percent in CAT, 52 and 75 percent in SOD, and 62 and 49 percent in GPx after MLR and MR consumption ($P<0.001$), respectively. ORAC increased after MLR ($P=0.004$). No significant alteration in lipid peroxidation biomarkers was observed. These effects may be important in
protecting biological systems and reducing the risk of diseases related to oxidative stress (Correa *et al.*, 2012)

The effect of Mediterranean-type diet and close dietetic supervision on dietary antioxidant intake and plasma total antioxidant capacity in patients with abdominal obesity was determined by Kolomvotsoul *et al.*, (2012). Following a two month period of close dietetic supervision following a specific relevant daily and weekly food plan with consumption of antioxidant-rich foods and food products, it was observed that adherence to a Mediterranean-type diet, with emphasis on an increase in foods rich in antioxidants and close dietetic supervision, can increase total dietary antioxidant intake and plasma TAC in patients with abdominal obesity.

Nalsen *et al.*, (2006), investigated the associations between dietary antioxidants and antioxidant-rich food items ans antioxidant capacity, as well as lipid peroxidation in vivo in 86 healthy subjects with a mean age of 60. The antioxidant capacity (AOC) assessed by cheniluminescence assay was $487.1 \pm 87.5 \mu\text{mol of TE/L}$. The results of this study showed that individuals with a higher intake of various antioxidant-rich foods, including different antioxidants, have better plasma AOC. The associations tended to be stronger between plasma AOC and different antioxidant-rich foods, when the foods were combined. An optimal antioxidant status may be achieved by eating a balanced diet rich in a mix of various antioxidant-containing foods. Moreover, the results indicate that lipid peroxidation in vivo is not easily affected by the diet.

The effect of pomegranate fresh fruit consumption on the plasma antioxidant capacity in 30 healthy volunteers was assessed by Hajmahmoodi *et al.*, (2008). The obtained data revealed that the consumption of 100 gm of pomegranate and vitamin E (400 units per day) for 10 days resulted in a significant increase in plasma antioxidant capacity.

Prior *et al.*, (2007), have demonstrated that consumption of certain berries and fruits such as blueberries, mixed grape and kiwifruit, was associated with increased plasma antioxidant capacity in the postprandial state and consumption
of an energy source of macronutrients containing no antioxidants was associated with a decline in plasma antioxidant capacity. However, without further long term clinical studies, one cannot necessarily translate increased plasma AOC into a potential decreased risk of chronic degenerative disease. Preliminary estimates of antioxidant needs based upon energy intake were developed. Consumption of high antioxidant foods with each meal is recommended in order to prevent periods of postprandial oxidative stress.

Di Renzo et al., 2007, compared the ORAC values of organic and conventional foods and verified if the consumption of these foods has an influence on the plasma antioxidant capacity in ten healthy Caucasian Italian men who were non smokers. They observed that the organic foods had higher antioxidant capacity than conventional foods and they observed a significant increase (21 percent) in plasma antioxidant capacity from baseline value of 2.25mM TE/L.

The influence of a Mediterranean dietary pattern on plasma total antioxidant capacity after 3 years of intervention and the associations with adiposity indexes in a randomized dietary trial with high cardiovascular risk patients was assessed by Razquin, C et al, 2009. Mediterranean diet, especially rich in virgin olive oil, is associated with higher levels of plasma antioxidant capacity. Plasma TAC is related to a reduction in body weight after 3 years of intervention in a high cardiovascular risk population with a Mediterranean-style diet rich in virgin olive oil.

Gifkins et al., 2012, evaluated the role of total dietary antioxidant capacity and of individual antioxidants on endometrial cancer risk in a population-based case–control study in New Jersey, including 417 cases and 395 controls. Dietary intake was ascertained using a food-frequency questionnaire (FFQ), and total antioxidant capacity intake was estimated using the USDA Oxygen Radical Absorbance Capacity (ORAC) database and the University of Oslo’s Antioxidant Food Database (AFD) and FFQ-derived estimates of intake. Odds ratios and 95 percent confidence intervals were derived using multivariate logistic regression controlling for major endometrial cancer risk factors. Using the ORAC database, after adjusting for major covariates, we found decreased risks for the highest
tertile of total phenolic intake compared with the lowest (OR: 0.62; 95 percent CI: 0.39–0.98). There was no association for TAC intake based on the AFD, which utilized the FRAP assay to assess antioxidant capacity. There was no strong evidence for an association with intake of any of the individual antioxidants. Our findings suggest that total phenolic consumption may decrease endometrial cancer risk.

According to Lopez-Legarrea et al. (2013), dietary strategies seem to be the most prescribed therapy in order to counteract obesity regarding not only calorie restriction, but also bioactive ingredients and the composition of the consumed foods. Dietary total antioxidant capacity is gaining importance in order to assess the quality of the diet. They evaluated the effects of a novel dietary program with changes in nutrient distribution and meal frequency and compared it with a diet pattern based on the American Heart Association guidelines. Anthropometric and biochemical parameters were assessed at baseline and at the endpoint of the study, in addition to 48-hours food dietary records. They observed both diets equally (p > 0.05) improved metabolic syndrome symptoms manifestations. Dietary TAC was the component which showed the major influence on body weight (p = 0.034), body mass index (p = 0.026), waist circumference (p = 0.083) and fat mass (p = 0.015) reductions. Transaminases (ALT and AST) levels (p = 0.062 and p = 0.004, respectively) were associated with lower TAC values. Dietary TAC was the most contributing factor involved in body weight and obesity related markers reduction.

According to Valtuena et al.,(2008), qualitatively selecting food items on the basis of their TAC is a useful and effective approach to demonstrate that, in addition to the quantity, the quality of certain food groups may be crucial to decreasing hepatic and systemic inflammation, both of which are independent risk factors for chronic disease. In the meantime, giving preference to foods naturally high in TAC could be a simple approach to further improving dietary habits.