INTRODUCTION

Changing lifestyles and environment have led to great changes in the health profile of the human population. Higher stress levels among individuals, sedentary lifestyle and deficient diets have increased the onset of degenerative and non-communicable diseases like cancer, diabetes mellitus and cardiovascular disease. Increase in environmental pollution whether it is noise, dust, radiation or pollutants have directly or indirectly contributed to the aggravation and sometimes onset of the above mentioned diseases.

One of the common pathways by which the causative factors initiate or promote the disease in the human system is through the generation of free radicals. The prevention of the onset of these diseases, in the above perspective, target at quenching free radicals to prevent further complications besides facilitating cure.

Antioxidants play a very important role in the body’s defence system against Reactive Oxygen Species (ROS), which are the harmful by-products generated during normal cell aerobic respiration (Gutteridge and Halliwell, 2000). Antioxidants are also quenchers of free radicals and increasing the intake of dietary antioxidants may help to maintain an adequate antioxidant status and, therefore, the normal physiological function of a living system and play an important role in preventing diseases.

Antioxidant defense mechanisms include cellular and extracellular enzymes such as glutathione reductase, superoxide dismutase, catalase, and free-radical scavengers, including vitamins C and E, carotenoids, glutathione, serum albumin, and metabolites such as bilirubin and uric acid. Vitamins C and E are antioxidants derived from the diet. Vitamin C scavenges free radicals in the aqueous phase, and the lipid-soluble vitamin E acts in vivo to prevent the formation of lipid peroxides and thus protect cell membranes (Rumbold et al., 2006).
Vitamin C plays an essential role as an antioxidant in cells containing a vast excess of glutathione. Vitamin C works with glutathione to provide the endothelial cells with the capacity to survive under conditions of oxidative stress, and that full antioxidant protection requires the simultaneous presence of intracellular and extracellular vitamin C at concentrations that are normally observed in vivo (Montecinos et al., 2007). The best-established biochemical function of vitamin E is its action as a lipid antioxidant and it is concluded that it is a superb chain-breaking antioxidant that appears to be the only major lipid-soluble antioxidant of its kind in mammalian membranes and lipoproteins.

Many phytochemicals have been found to possess antioxidant property and additional functions such as preventing carcinogenesis. The role of diet rich in bioactive plant based phytochemicals as an adjunct therapy is gaining importance with the awareness on the role of such natural compounds.

The regular consumption of polyphenols has been associated with a decreased risk of a number of degenerative diseases including cancer, cardiovascular diseases and neurodegenerative disorders. Rather than exerting direct antioxidant effects, the mechanisms by which polyphenols express these beneficial properties appear to involve their interaction with cellular signalling pathways and related machinery that mediate cell function under both normal and pathological conditions (Vanzour et al., 2010).

Flavonoids are an important class of polyphenols which are widely distributed in plant foods as individual compounds or bound to saccharides as glycosides. In addition to their antioxidant properties, flavonoids have been reported to exhibit other multiple biological effects like antiviral, antibacterial, anti-inflammatory, vasodilatory, anticancer and anti-ischemic effects (Procházková et al., 2011).

Resveratrol, a chemo protective agent, found naturally in foods like red grapes, red wine peanuts and berries has shown to possess chemoprotective properties against several cancers and cardiovascular diseases. Resveratrol has been shown to inhibit tumor initiation, promotion and progression. There is growing
Appendices

Total antioxidant capacity of commonly consumed Indian foods and Plasma antioxidant status of Indian adults

Evidence that resveratrol can prevent or delay the onset of various cancers, heart diseases, ischemic and chemically induced injuries, pathological inflammation and viral infections (Shankar et al., 2007).

Lycopene, a carotenoid found in tomatoes is an antioxidant with a protective effect on lipid peroxidation and anti-atherosclerotic activity (Reid and Fakler, 2011). Lycopene has antioxidant and anticancer activities by having a barrier integrity activity and inhibitory activity on cell adhesion and migration to endothelial cells (Bae and Bae, 2011). Observational studies indicate that green tea may provide protection against hypertension and reduce the risk for stroke, and interventional studies are providing biochemical and physiological evidence (Clement, 2009).

Many such compounds have been isolated from plant foods, mainly fruits, green leaves and vegetables, which have been identified to play a protective role in the human system and such plant foods have gained importance owing to their antioxidant content. Fruits and vegetables have historically held a place in dietary guidelines because of the high concentrations of vitamins in them, especially vitamins C and A; minerals, especially electrolytes; and more recently phytochemicals, especially antioxidants (Slavin and Lloyd, 2012).

The consumption of fruits and vegetables has been associated with a reduction in the risk of developing degenerative and chronic diseases. To tackle the rise in non communicable diseases, the World Health Organisation (WHO) has recommended the promotion of fruit and vegetable intake as a crucial component in any global diet strategy (Lock et al., 2005).

Fruit and vegetable consumption is inversely associated with the risk of Coronary Heart Disease (Dauchet et al., 2006). The intake of fruits and vegetables varies greatly across countries, settings, ages, genders and income levels (Hall and Moore, 2009) and is generally less than recommended levels in developing countries including India (Yadav and Krishnan, 2008). A higher intake of fruits and
vegetables in healthy elderly is associated with a healthy antioxidant status in comparison with subjects consuming diets poor in fruits and vegetables (Polidori et al., 2009).

Anthocyanins and proanthocyanidins that give a vibrant colour to berries are powerful antioxidants. Phenolic compounds and flavonoids are widely present in fruits and vegetables which contribute to their antioxidant power. Soft fruits such as raspberries, strawberries and blackcurrants contain several classes of soluble (polyphenol) antioxidants like anthocyanins, flavanols, flavones, flavanones and catechins, apart from vitamin C (Stewart et al., 2013).

Mandarins, oranges, peaches, apples and apricots all have high antioxidant capacity. Vegetables like Broccoli, cauliflower and leek exhibit high polyphenol activity (Dragovic et al., 2009).

Green leafy vegetables are identified as a rich source of beta carotene. Apart from carotenoids, they contain many bioactive components and are found to have the highest antioxidant capacity than some fruits and root vegetables (Jimaima Laco, 2007).

Green leafy vegetables are rich in phenolic acids and flavanoids (Nambiar et al., 2010) which are potent antioxidants and help in preventing cardio vascular (Morton et al., 2000) and some chronic diseases (Knekt et al., 2002). A higher intake of dark green leafy vegetables or dark yellow vegetables has been significantly associated with reducing risk of type 2 diabetes mellitus (Liu et al., 2004).

There are many fruits and vegetables indigenous to India especially green leafy vegetables besides curry leaves and coriander leaves. Amaranth species, drumstick leaves (Moringa sp), fenugreek leaves are a few, the information about the antioxidant capacity of which is scanty.

Cereals, being the staple food, form the major part of the Indian diet. Whole grains and millets also have unique phytochemicals different from fruits and
vegetables but have not received much attention apart from being rich sources of energy and fibre. The bran and germ of the whole grains are found to be rich in antioxidants and vitamins (Marquat et al., 2002).

Sorghum is a good source of phenolic compounds with a variety of genetically dependent types and levels including phenolic acids, flavanoids and condensed tannins (Dykes and Rooney, 2006). Finger millet, foxtail millet, proso millet, pearl millet is important sources of antioxidants of which pearl millet is an important crop in India. Pearl millet possesses high phenolic content, moderate reducing ability and high free radical scavenging activity and therefore can serve as a source of antioxidants in our diets (Odusola et al., 2013).

Pulses and root vegetables also form an integral part of Indian diet and some of these foods have been identified to be rich in antioxidants. Soybean, rich in isoflavones is also rich in phenolic acids and has a high antioxidant capacity (Kugler et al., 2007). There are other types of pulses, namely, bengal gram, black gram, green gram, red gram which are used in India and data on the antioxidant capacity of these foods is very limited.

Roots and tubers like carrot, beetroot and turnip have been studied for the carotenoids, pigments and vitamins, especially vitamin C, which contribute to the antioxidant capacity of these vegetables and red beetroot extracts have shown high antioxidant capacities in different test systems (Ranilla et al., 2009).

Potatoes are widely consumed both in western countries and in India and pigmented potatoes contain high concentration of antioxidants including anthocyanins, phenolic acids and carotenoids (Vinson et al., 2012). Many varieties of root vegetables like yam, seppankilangu, koorgankilangu are conventionally used in India and the data on the antioxidant content of these foods is scarce.

More than the individual phytochemicals, it is the addictive and synergistic effect of these that benefit. A systematic review (Bjelakovic et al., 2007) have revealed that beta carotene, vitamin A, and vitamin E given singly or combined with other antioxidant supplements may increase mortality. There is no evidence
that vitamin C may increase longevity. We lack evidence to refute a potential negative effect of vitamin C on survival. Selenium tended to reduce mortality, but we need more research on this question.

In contrast to supplements of single antioxidants, the dietary total antioxidant capacity reflects all present antioxidants, including thousands of compounds, all of them in doses present in our usual diet, and even takes into account their synergistic effects.

Dietary Total Antioxidant Capacity (TAC), based on fruits, vegetables, coffee, and whole grains, is of importance in the prevention of myocardial infarction (Rautiainen et al., 2012). This has shifted the focus to overall dietary patterns and food intake rather than single nutrient intakes (Lichtenstein and Russell, 2005).

A diet rich in antioxidants based on antioxidant rich food consumption and not on single antioxidant administration, can increase the antioxidant status of the organism and offer better health (Limberaki et al., 2009). Dietary TAC, as a measure of antioxidant intake, may also be a potential marker of diet quality in healthy subjects, providing a novel approach to assess the role of antioxidant intake on health promotion and diet-based therapies (Puchau et al., 2009).

Experimental studies suggest that oxidative stress and systemic inflammation are involved in the pathogenesis of ischemic stroke. Consuming a diet with a high total antioxidant capacity has been related to reduced inflammation and increased circulating antioxidants in cross-sectional and randomized intervention studies (Del Rio, 2011).

Therefore, measuring the TAC of foods will be helpful in calculating the dietary TAC as a whole. The complex mixture of phytochemicals in foods and their synergistic effect make their individual assessment difficult and hence the Total Antioxidant Capacity along with Total Phenols (TP), since phenolic acids are widely prevalent in foods, will provide the overall measure of the antioxidant effect.
of the food. Moreover, cooking and processing have a profound influence on the antioxidant capacity of foods. Foods are cooked mostly by boiling in water, frying and pressure cooking methods.

Cooking brings about significant change in the texture and chemical composition of foods including antioxidants. Boiling and baking have a small effect on the ascorbic acid, total phenolics and lycopene content of tomatoes whereas frying tomatoes significantly reduced their ascorbic acid, total phenolics and lycopene content (Rehman et al., 2003).

Plasma TAC will be a useful measure to assess the adequacy of intake of foods or the benefits of intake of antioxidant rich foods. The measure of antioxidant capacity of plasma considers the cumulative action of all the antioxidants present in plasma and body fluids, thus providing an integrated parameter rather than the simple sum of measurable antioxidants. The capacity of known and unknown antioxidants and their synergistic interaction is therefore assessed, thus giving an insight into the delicate balance in vivo between oxidants and antioxidants.

Measuring plasma antioxidant capacity may help in the evaluation of physiological, environmental, and nutritional factors of the redox status in humans. Determining plasma antioxidant capacity may help to identify conditions affecting oxidative status in vivo (e.g., exposure to reactive oxygen species and antioxidant supplementation). Moreover, changes in the plasma antioxidant capacity after supplementation with galenic antioxidants or with antioxidant-rich foods may provide information on the absorption and bioavailability of nutritional compounds (Ghiselli et al., 2000).

There are reports of increase in plasma antioxidant capacity after the consumption of antioxidant rich foods. For example, 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 (Prior et al., 2007).
Given the potential benefits of consuming antioxidant rich foods, the intake of such foods in developing countries like India, needs consideration. The dietary guidelines for Indians recommends an intake of 100g of fruits and 400g of vegetables for Indian adults of which 100 g should be green leafy vegetables, 200g of roots and tubers and 100g of other vegetables. National Nutrition Monitoring Bureau (NNMB) surveys indicate that the daily intake of foods including cereals and millets (345g) in Indian households is lower than the Recommended Dietary Allowances or RDA.

The average consumption of pulses and legumes like green gram, bengal gram and black gram, which are important poor man's source of protein was about 31 percent lower (24g) than the RDA of 35g per CU/day. Consumption of green leafy vegetables (<14g) and other vegetables (43 g), which are rich sources of micronutrients like betacarotene, folate, calcium, riboflavin and iron, was grossly inadequate. Intake of visible fat was about 71 percent of the RDA (Narasingha Rao, 2013).

In the state of Tamil Nadu the average consumption of green leafy vegetables is 10 g, the consumption of other vegetables and roots and tubers is 41g each and the consumption of fruits is nil. The highest intake has been reported in the state of Orissa where 47g, 64g and 64g of green leafy vegetables, other vegetables and root vegetables are consumed respectively (NNMB).

The consumption of cereals is almost close to the recommended guidelines but rice, wheat and their products are the major cereals consumed in India. Though millets and coarse grains, some of which have been studied to have high antioxidant capacity, are available at a low cost, the consumption of these is comparatively low.

Given the present scenario on the importance of antioxidants, consumption of antioxidant rich foods and inadequate consumption of such foods in India, it is important that sufficient data is made available on the antioxidant content of foods commonly available in India which would provide an opportunity for people to include foods rich in antioxidants.
Also, a measure of the plasma antioxidant capacity and the influence of diet on the plasma TAC will provide valuable information on diet patterns that can be promoted to maintain a healthy life. Hence the research titled ‘Total antioxidant capacity of commonly consumed Indian foods and Plasma antioxidant status of Indian adults’ was undertaken with the following objectives. To

- Select commonly used Indian foods
- Estimate the total antioxidants in the selected Indian foods represented as Oxygen Radical Absorbance Capacity (ORAC) and Ferric Reducing Antioxidant Power (FRAP) values
- Estimate the total phenols in the selected foods
- Evaluate dietary intake and the total antioxidant capacity of the diet of healthy adults.
- Analyse the plasma antioxidant status of selected healthy adults.