REVIEW ARTICLE

TEA POLYPHENOLS: VARIATION WITH RESPECT TO AGRO-CLIMATIC CONDITION, THEIR IMPACT IN HUMAN HEALTH AND SOIL ENVIRONMENT.

Tarun Kumar Misra* and Palash Mandal±

* *Institute of Plantation Science and Management (Tea Management), University of North Bengal, Darjeeling 734013, India.*

±*Department of Botany, University of North Bengal, Darjeeling 734013, India*

"There is light enough for those who wish to see and darkness for those of the opposite disposition" – Blaise Pascal.

Abstract

Tea is the richest source of different kinds of polyphenols and potential antioxidants. In recent years numerous biochemical and physiological studies have demonstrated that accumulation of polyphenols in tea is significantly related to soil nutrient availability. In this review recent advances in current understanding of bioactive polyphenols and their accumulation in tea plant have been discussed concisely.

Key Words: - Tea poly phenols → Ecological significance → Physiological Interaction → Soil nutrition → Bio-availability

Back Ground: -

Thea or tea consists of the prepared leaf bud of *Camellia sinensis* (L.) O. Kuntze (Fam.Theaceae), a shrub or tree with alternate, evergreen leaves. The Tea tree is indigenous to Eastern Asia and is now extensively cultivated in China, Japan, India & Indonesia. The generic name is from the Greek meaning goddess; sinensis refers to its Chinese origin.

The tea tree is a acid loving, generally grown in sandy-loam soil whose pH is in between 4.5 to 5.5 and rich soil organic carbon [C%> 1.00%, av. K_2O (ppm) > 100, av. P_2O_5 (ppm) - 20-30, av. S (ppm) > 40]. It is mostly cultivated in the tropical belt of 44° N to 34° S and grown in slopes of hills, flats and plateaus at altitudes varying below 700m & above 2400 meter from sea level. Temperature above 35.0°C and below 12.5°C are not congenial for tea cultivation. Tree tea is a rain fed crop grows well in areas having annual precipitation of 100 cm. to 300 cm. Persistent drought condition could be lethal for the bush; irrigation during drying month could be beneficial.

Objectives: -

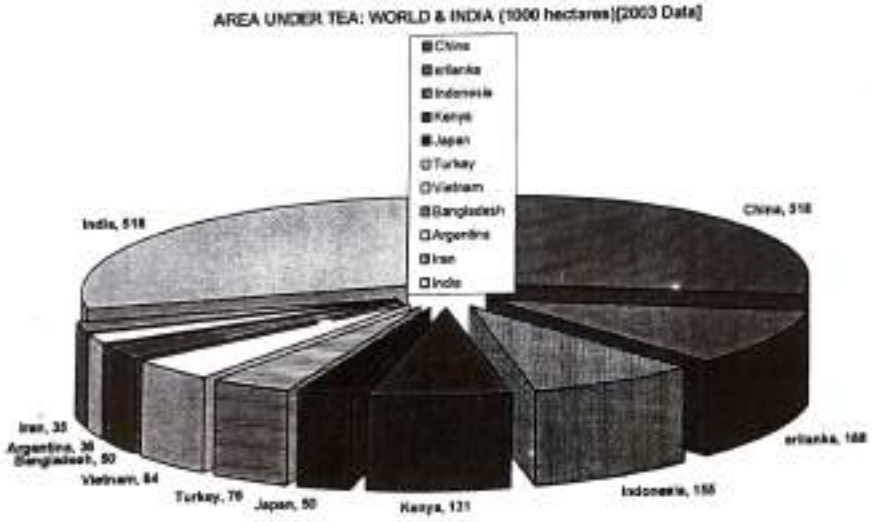
Our write-up is an attempt to highlight the most promising health benefits of tea consumption documented during the last few decades in India and all over the world. Our another attempt is to draw relationship between polyphenols and the parameters of soil, climate, topography, variety of clone, categories of tea affecting the antioxidant property and the environmental quality of tea mono-culture.

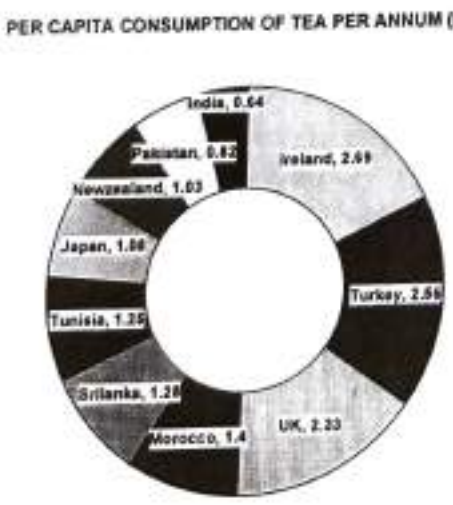
Introduction:-

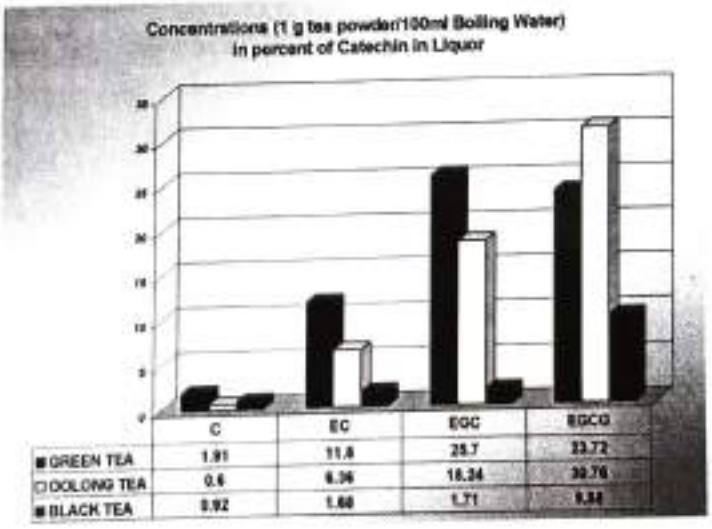
Aspects & prospects of tea

Polyphenols, the principal chemical constituent of tea, estimates for about 20.098% in tea shoots (g/100g dry wt.) (Dev Choudhury *et.al.* 1983). Tea is used as beverage and has been practiced by mankind since any where between 500-5000 years ago (Gutman *et. al.* 1996). In Far East, Mythologically tea was used as beverage and health elixir. The conventional use of tea has prompted scientific investigation employing modern research technology in China, Japan and US on the influence of tea consumption on human health since mid 60. As a result by 1980-1990, green tea became popular for its health benefits world wide. In that time maximum scientific data were generated for claming the consumption of tea which has exclusive preventive effects over several degenerative diseases. Simultaneously information from scientific world on life-style and impact of diet on human health has been increasing immensely.

India is the largest tea producing country in the globe. In India collaborative research was launched between TRA and IICB in 1990 with the objective to evaluate the medicinal valued black tea as is consumed.





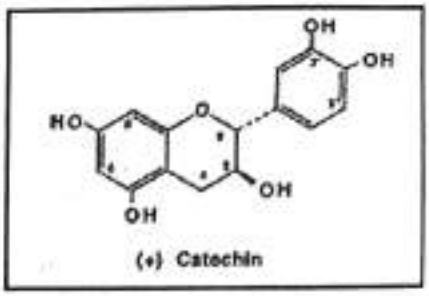


Bio-Chemistry of Poly-phenols:-

Biosynthesis of Polyphenols in tea plants – A combination of shikimate and acetate pathways are as follows –

Shikimic acid → Phenyl pyruvic acid → Phenyl alanine → Cinnamic acid → p-coumaric acid → Flavanol → EC → EGC → ECG → EGCG

Gallic acid



Classification –

Tea Poly-phenols

Non Flavonoids Poly-phenols

eg. Hydrolysable tannins

Flavonoids

- Largest group of Poly-phenols
- Common C_6-C_3-C_6 Skeleton

Flavanols

Catechins (C)

(Green tea)

Gallocatechin (GC)

Epicatechin (EC)

Epigallocatechin (EGC)

Epigallocatechin-3-Gallate (EGCG)

Flavonols and Flavonols glycoside

Acids and Depsides

Gallic acid,

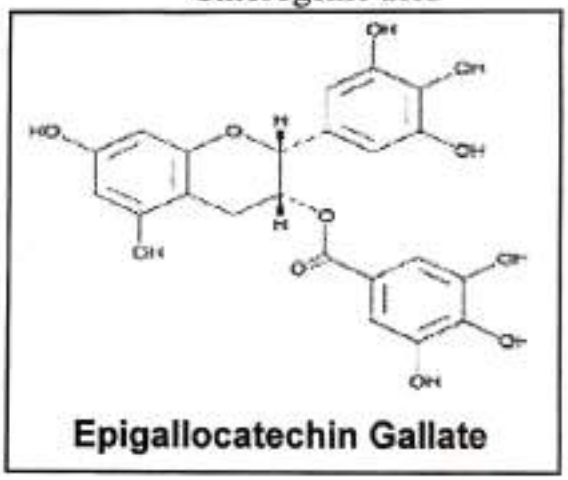
Chlorogenic acid

Theaflavins

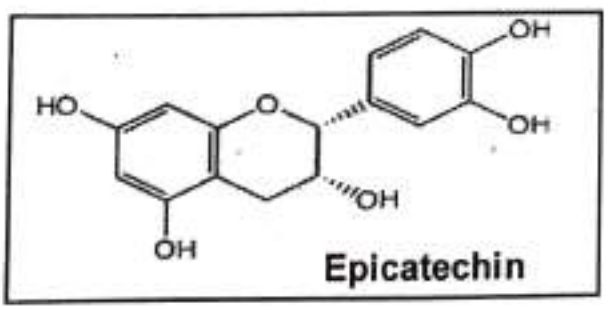
(Black tea)

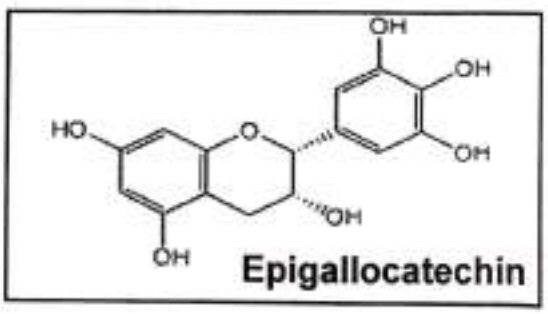
Thearubigins

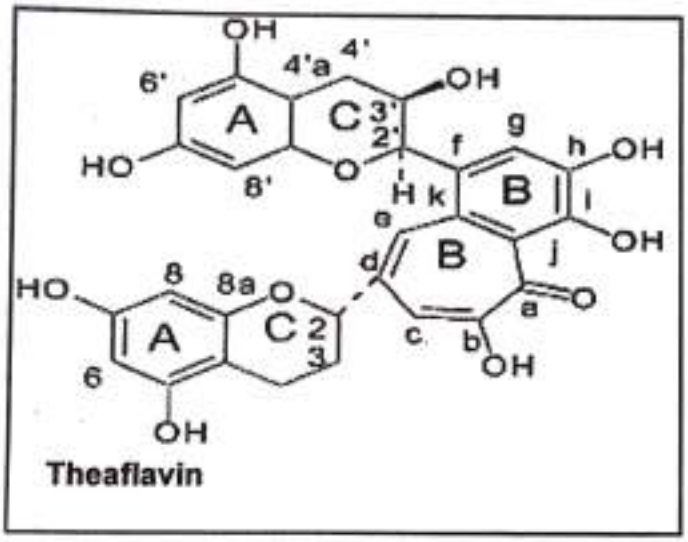
(Black tea)

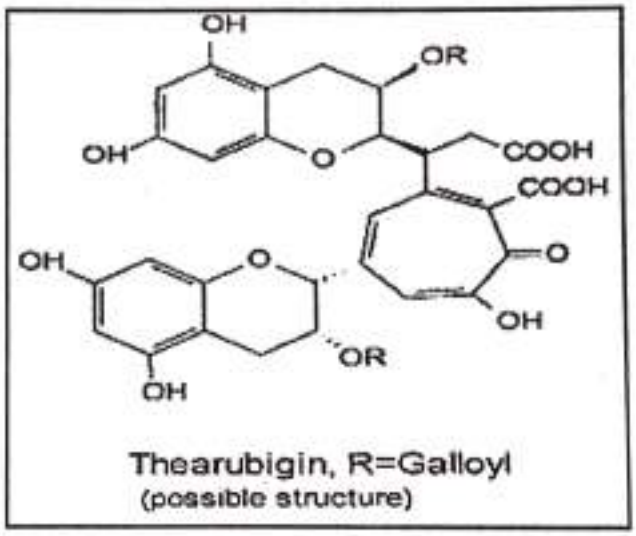


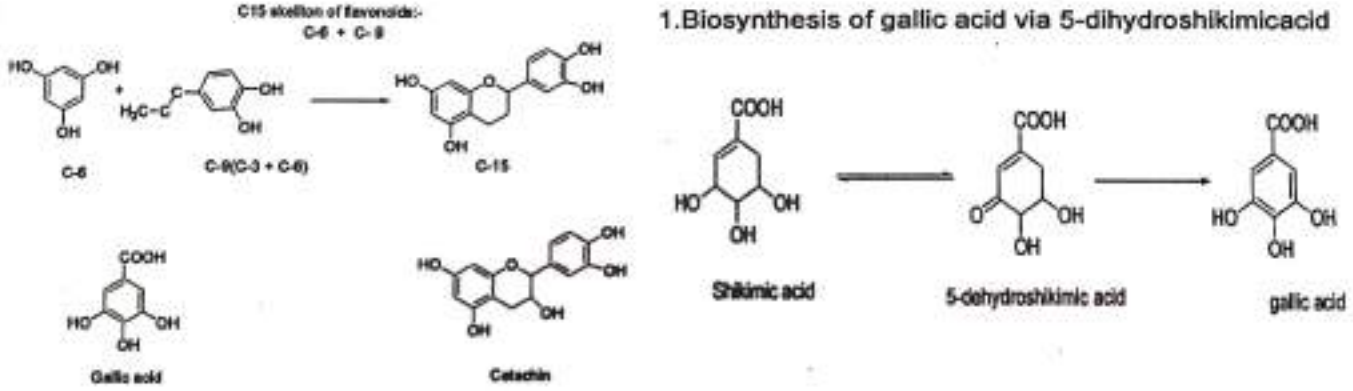
Flavonoids are derived from variety of simple poly-phenolic units. The hydroxylation pattern of B-ring of flavonoids and their different substitution are principally important for executing their bioactivity. They have potential role in plant defense, reproduction and antioxidants.

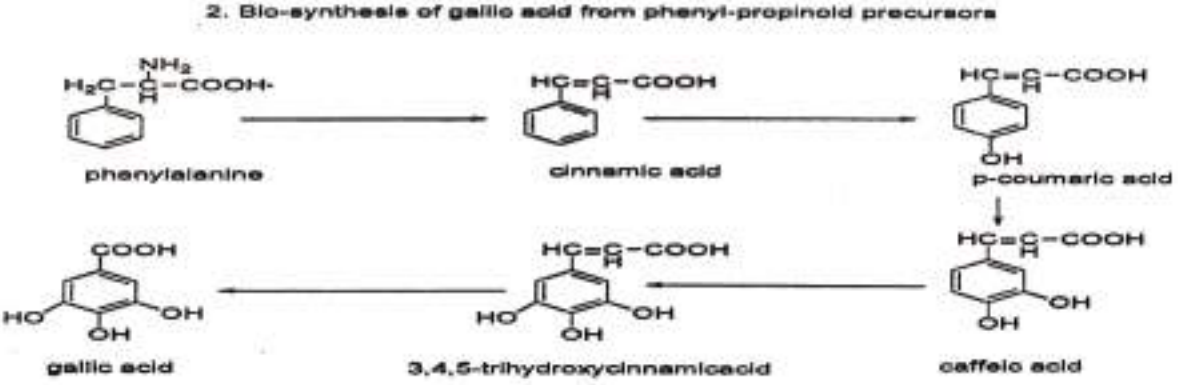








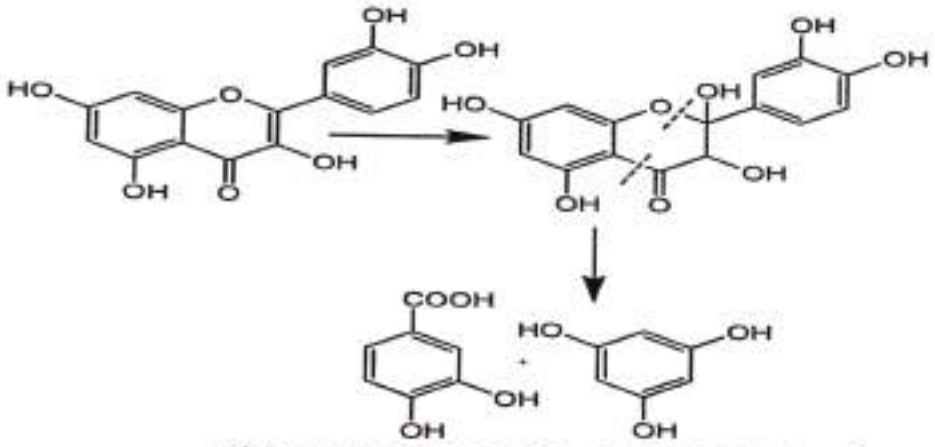




Storage and degradation of polyphenol in plants: -

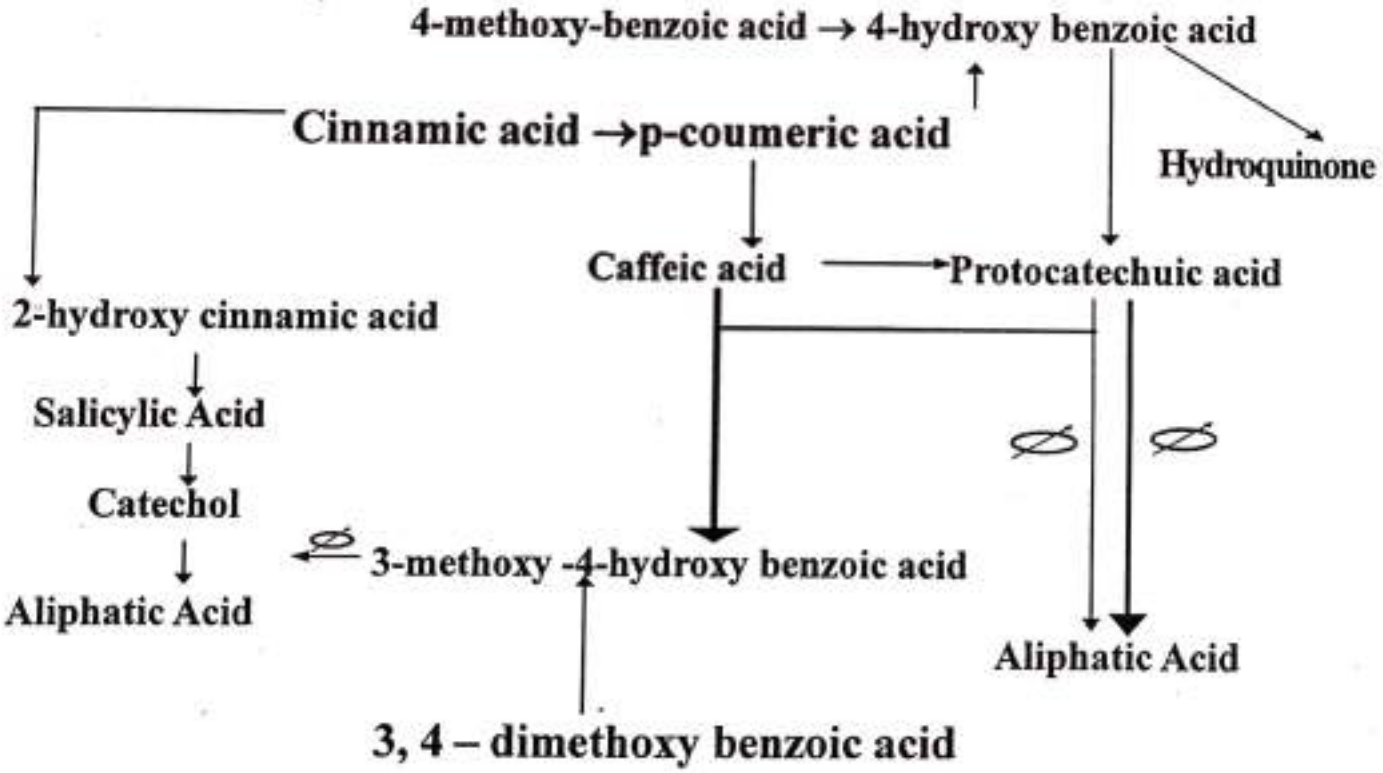
More often polyphenols are found in vacuoles and tea leaf cell; epidermal layers are the sites for their oxidation which are performed by the enzyme PolyPhenol Oxidase. The early stage of the catabolism of flavonoids involves the addition of oxygen to the 2, 3 double bond to give a 2-hydroxy derivative. This 2, 3 - dyhydroxy flavonone is then undergoing ring-cleavage to give a substituted benzoic acid and a pholoroglucinol derivative, which may not be detectable because of its immediate oxidation. Undoubtedly the end products are eventually returned to the atmosphere as respired CO_2.

Fig.-1 Metabolic fate of flavonol quercetin in plants –



Hydroxy cinnamic acid →→hydroxy benzoic acid →→→ CO_2.

The fate of simpler phenolic compounds in plant tissues has been extensively studied and summarized schematically in Fig.-2



Polyphenols and their relation to soil fertility:-

Sivapalan *et.al.* in 1993 examined the comparative effects of phenol rich and phenol poor plant residues after prolonged decomposition on the urease activity of an acid soil. Addition of organic residues increased soil urease activity over that of control; but soil amended with phenol rich residues had a urease activity which was about 50% lower than that of soil amended with phenol poor residues. This reduction in soil urease activity was attributed to the higher content of soil polyphenols present in the soils amended with phenol rich residues.

The polyphenols of fresh green and dried leaves, litter of superficial humus from mull of mor site were examined by Coulson *et.al.* 1960, and observed the greatest diversity and quantity of phenolic substances obtained in the extract of fresh beech leaves from mor site. There was a change in quantity of simple polyphenols grading from a maximum in fresh growing green leaves, falling through senescent leaves to dead leaves to fresh fallen leaves, to a minimum decayed leaves and humus or stored dry leaves. Tannin Stripping and especially hydrolysis and reduction of the decayed leaves and superficial humus particularly release polyphenolic substances in the soil.

It has been discussed (Harborne 1980) that Nitrogen and Phosphorus deficiency usually increase the flavonoid levels and Boron deficiency may increase hydroxy-cinnamic acid levels at the expense of flavonoids or lignin.

The application of compound fertilizers increased available P, K and Mg content in soil but decreased alkali-hydrolysable-N and NPK content, compared with the urea treatment. Application of compound fertilizers could improve the quality of tea and increase their yield by 0.551 to 1.3 tons/hector and enhance their profit significantly by 10.0% to 15.7%. (Rui *et.al.* 2006).

Ecological significance:-

The concentration of flavonoids in tea leaves changes during the development of tea shoots i.e. spring tea; summer tea and a 3rd-crop tea differ to some extent. It is evident that flavonoid accumulation is higher in summer than in spring and also apical bud + 2 leaves are richer in polyphenols than old leaves. The contribution of ploy phenols in the cell vacuoles are self evident; flavones and flavonols present in the flower tissues are essential as co-pigments associated with the anthocyanin and also occasionally concerned as a hidden UV honey guides for attracting green fly to the tea flowers.

Other ecological roles for phenolics are observed in nature. Some phenolic derivatives act as allelopathic agents. Certain chemicals are excreted by the plant which may be auto toxic or affect the growth of others plant in the environments (Rice, 1974). Also it has been found that flavonoids, especially tannins, have a role as feeding deterrents, protecting plants from overgrazing by many animal species (Swain, 1977).

Physiological interaction:-

One important role of phenolics points on hormonal control that might affect the biosynthesis of ethylene. It is well known that a p-coumaric acid ester is a co-factor for ethylene biosynthesis from methionine in cauliflower floret (Mapson 1970). It is also a co-factor of peroxidase-like enzymes on the pathway on the pathway of Phenylpropanoids and it is interesting that caffeic acid at the site of the synthesis could theoretically provide a regulation on ethylene synthesis. Phenolics may react with other hormones by synergism or inihibition and both the situation have been recorded in case of plant growth stimulated by gibberelic acid. There is evidence that dihydro coniferyl alcohols in lettuce have synergistic effect on GA_3 stimulated elongation of hypocotyls (Kamisaka *et. al.* 1977). In contrast, substitution of dihydro coniferyl alcohol by any one of several common hydroxy cinnamic acids reverses this effect. It may be noted that tannins in other plant system have an antagonistic effect on GA_3 activity (Corcoran et. al., 1972). Many phenolics are capable of inhibiting ATP synthesis in mitochondria, uncoupling respiration and inhibiting ion absorption in roots (Stenlid 1970). Flavonoids may also affect the polar transport of

auxins (Stenlid 1976) and protoplasmic streaming in root hairs (Popovici *et. al.* 1976).

Tea as powerful Antioxidants:-

The most commonly consumed flavonoids, catechins are in tea. These compounds have a wide range of antioxidant activity (Wiseman *et. al.* 1997) Electron paramagnetic resonance experiments demonstrated the quenching of singlet oxygen, super oxide anion, and hydroxyl radicals by black and green tea extracts (Kondratyuk *et. al.* 2004). H_2O_2 and Primaquine induced lipid peroxidation is prevented by prior incubation with tea polyphenols. The tea polyphenols inhibit hydroxy radical fluxes generated by an iron-ascorbic acid system, suggesting that iron chelation may be a role in polyphenol action. Tea flavonoids inhibit macrophase of human umbilical vein endothelial cell induced LDL oxidation. Theaflavin-digallate was most effective in this case.

Absorption, bioavailability and fate metabolism of Polyphenols:-

Absorption – The absorption of the flavonoids in tea depends on its physico-chemical properties like molecular size, configuration, lipophilicity, solubility and pKa.value. To date only little information are available for determining the effect of the plant food matrix on absorption. Most of the flavonoids except catechins are usually present in the diet as β-glycosides.

Hydrophilic glycosides are absorbed by passive diffusion in the small intestine; therefore aglycone parts are only to be absorbed. Hollman in 2004 studied β-glycosides in onion and observed that the absorption was unexpectedly high; in this context it was claimed that quercetine glycosides are also absorbed in the small intestine. Hollman confirmed the above phenomenon by the pharmacokinetic studies in human model. This was explained by the transport of hydrophilic quercetine glycoside across the small intestine and it was proposed that the Na^+ dependent glucose co-transporter was involved. If the hypothesis related to Na^+ dependent metabolic pumping is true, the quercetine glycosides should have been transported across the enterocytes and may be accumulated in blood plasma. But in reality Quercetine-3-glycosides was absent in plasma even after proper supplementation of the same.

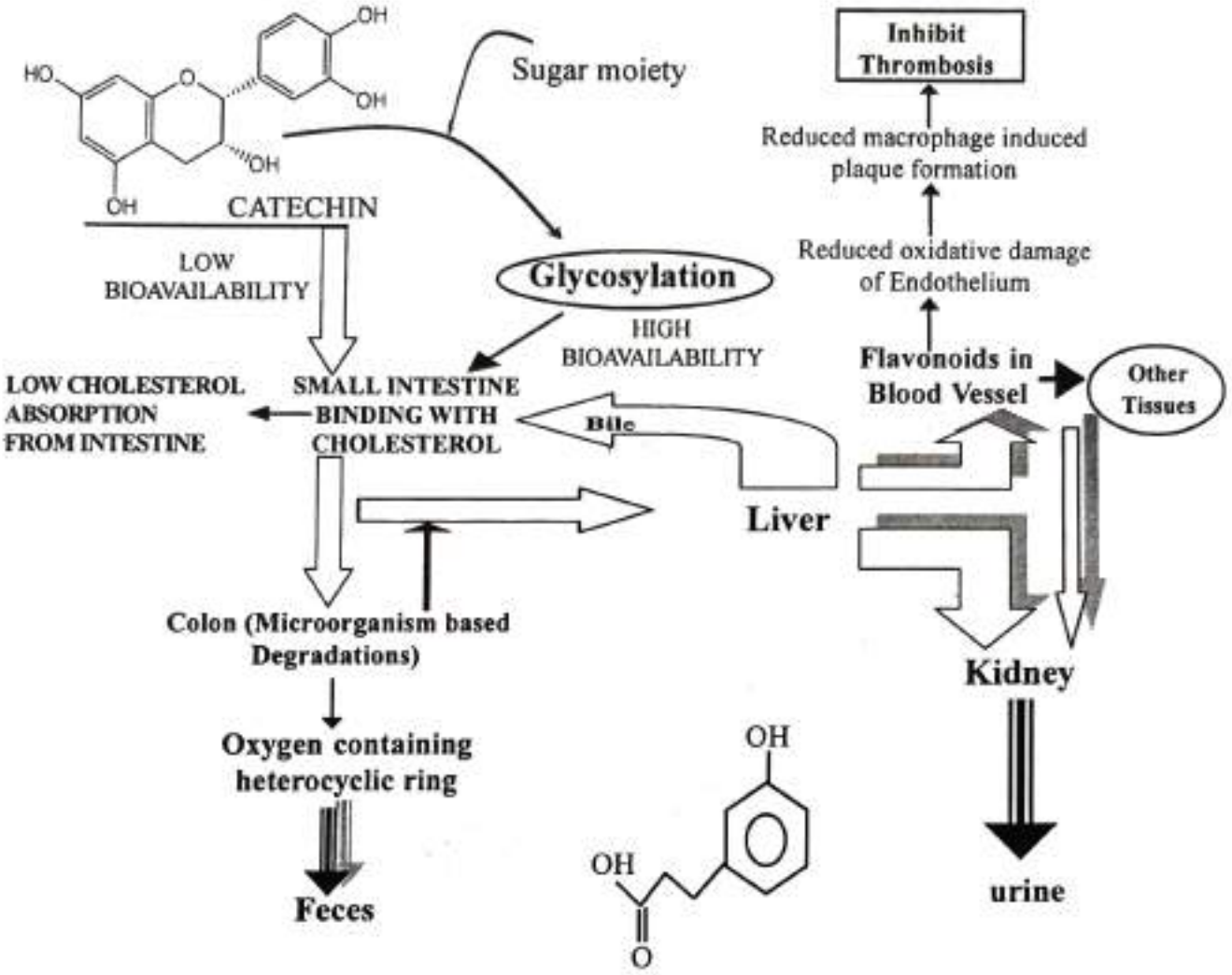
Colon bacteria are able to hydrolyse flavonoid glycosides but simultaneously they are capable to degrade & liberate flavonoid aglycones. This is also explained by the fact that the absorption capacity of the colon is less than that of the small intestine. The data supplied by Hollman et al., in 2004 strongly imply that the sugar moiety of quercetin glycosides is a major determinant of their absorption and bioavailability.

Bioavailability: - In man tea flavonol glycosides are absorbed very rapid to very slow. Comparative studies show that the bioavailability of different food supplements is dissimilar, it implies that important determinant of their bioavailability is the structural configuration of sugar moiety in flavonoid glycosides. It is also evident that catechins are quite absorbed from the small intestine; galloylated EGCG form is not different in this respect. Bioavailability of various catechin monomers is quite similar although dimerization decreases the bioavailability.

Metabolism: - The two compartments: small intestine, liver, kidney & the other compartment i.e colon are main sites of the metabolism of tea flavonoids. Absorbable form of flavonoids are secreted with bile & reached in the colon.

Mainly in the first compartment enzymes related to phenol metabolism act upon the substrates and their colonic metabolites; kidney also contain enzyme which is capable of biotransformation of polyphenols. Conjugation of polar hydroxyl group of flavonoids with glucuronic acid sulphate or glycine occurs during biotransformation. Inactivation of catechol moiety takes place by the

enzyme catechol –O-methyltransferase i.e O-methylation plays an important role.



Compartment involved in the metabolism of poly phenols and their impact on altered sclerotic plaque. Flow of flavonoid (⟹) Flow of colonic metabolites (⟹)

Black tea may prevent cigarette smoke-induced oxidative damage of proteins:-

The degenerative diseases that have been linked to oxidative damage caused by smoking are emphysema atherosclerosis (Misra *et al.* 2003), lung cancer and other malignancies. Epidemiologic reports and other experimental studies suggest that tea has chemopreventive effects against cigarette smoking and tobacco use. Almost one third of the world's are direct or indirect smokers and the hazardous effect of smoking is now a global public health problem with alarming threat. Encouraging the negative impact of smoking would unquestionably be the best measure to eradicate this deleterious practice. However, notwithstanding the warnings and anti-smoking campaign, smoking continues. Thus, a practicable approach is to find a way to prevent the deleterious possessions of smoking. Many scientific studies reveal that regular intake of tea may protect the smokers from nicotine-induced oxidative damage and the consequent degenerative diseases.

Oxidation in rheumatoid arthritis: - Oxygen metabolism has a crucial role in the pathogenesis of rheumatoid arthritis (Hitchon *et. al.* 2004). Reactive oxygen species formed in the course of cellular oxidative phosphorylation, and by activated phagocyte cells during oxidative burst, go above the physiological buffer capacity and resulting in oxidative stress. They also serve as important intracellular signal molecules that amplify the synovial inflammatory proliferative response. Repetitive cycles of hypoxia and deoxygenation are associated with changes in synovial perfusion. A thoughtful of the complex relations involved in genes is significant to the persistence of synovitis. Thorough understanding of the complex interactions involved in this pathway is essential for articulating the novel therapeutic strategies of rheumatoid arthritis; tea polyphenols can be used as alternative medicine for controlling cellular oxygenation from its earlier stage.

Tea catechins against *Helicobacter pylori* :- Tea catechins have an antibacterial effect (Mabe *et al.* 1999) against *H. pylori* and may have a therapeutic effect against gastric mucosal injury induced by this organism. A new, safe, and effective therapeutic regimen against *H. pylori* infection may be manufactured by the use of catechins combined with a proton pump inhibitor, perhaps in a delivery system which prolong the gastric-transit time of catechins.

Acute radiation induced skin toxicity:- Tea extracts are competent drug for patients who are suffering from acute radiation-induced skin toxicity (Pajohk *et al.* 2006). The molecular mechanism underlying the advantageous effects are complex, and most likely not solely dependent on effects of single tea polyphenol like epigallocatechin-gallate.

Tea extract maintains the restitution of skin integrity. It inhibits proteosome function and suppresses cytokine activity. Action of cytokine was altered by tea extracts in a complex, caspase-dependent manner, in association with epigallocatechin-gallate, an important component of tea. Moreover, both tea extract, as well as epigallocatechin-gallate, protect the macrophages from ionizing radiation to some extent.

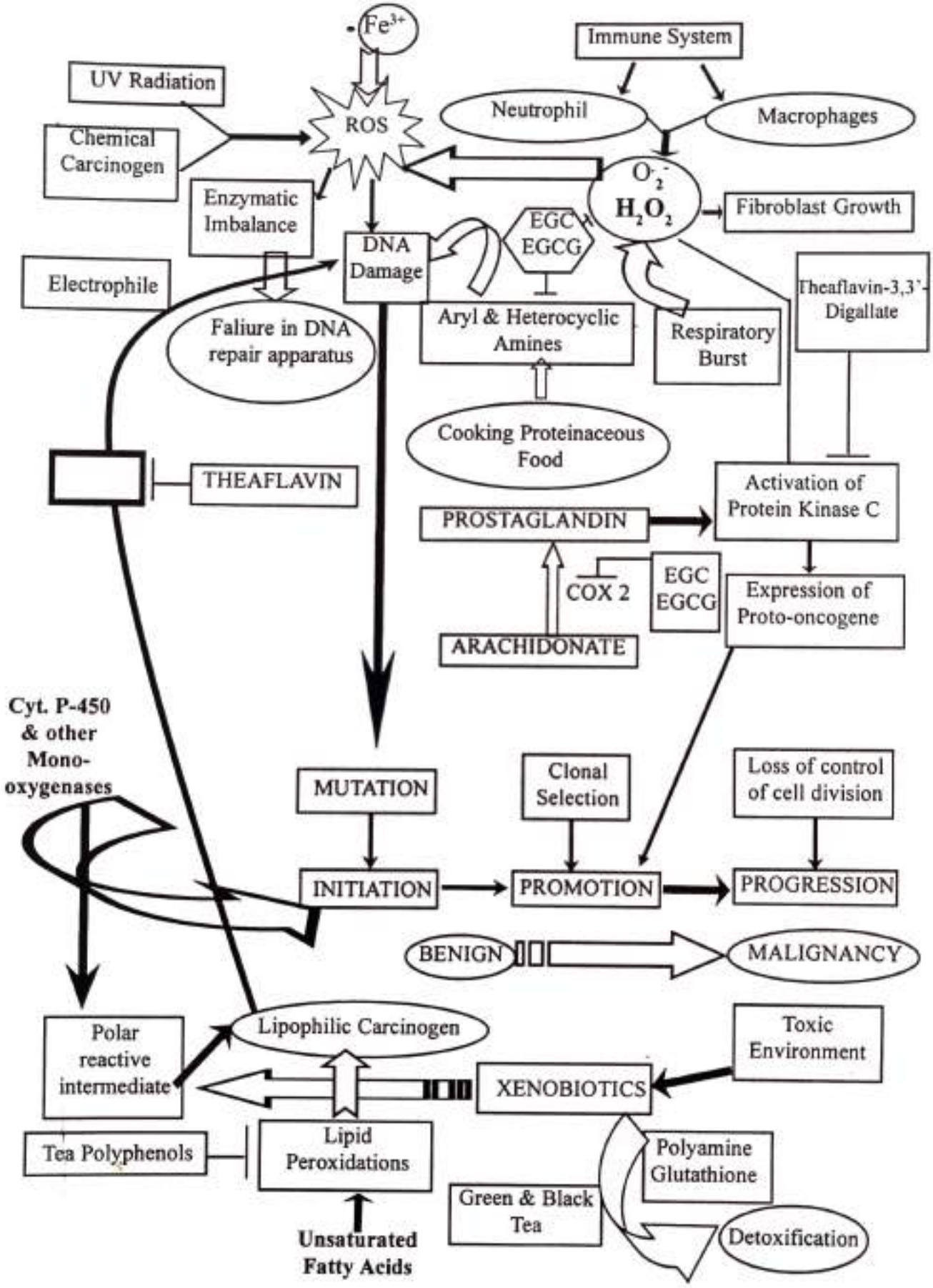
Toxin-induced hepatotoxicity:- In case of liver injury, there is also growing evidence that excessive NO production by iNOS plays a crucial role in the induction of toxin-induced liver injury (Chen *et. al.* 2004). Reaction of NO with superoxide anions produces peroxynitrile, which is a highly oxidative species, capable of nitrating tyrosine residue of numerous proteins, which leads to the formation of nitrotyrosine. Nitrotyrosine formation, detected by a specific antibody, was increased during hepatotoxicity and was significantly decreased by EGCG treatment.

Green tea polyphenol extract attenuate lung injury in pleurisi:- Green tea extracts, exerts a potent anti-inflammatory effect (Paola *et al.* 2005) at the time of acute inflammatory response haracterized by fluid accumulation in the pleural cavity that contains many neutrophils (PMNs). Infiltrations of PMNs in lung tissues increase the production of nitrite/nitrate, and tumour necrosis factor alpha. All parameters of inflammation were attenuated by green tea extract treatment.

Tea Poly Phenols is an anti-carcinogenic agent: - Occurrence of cancer is associated with

the natural loss of control of cell division in any tissue organs. Cell division or cell proliferation is a physiological process that occurs in almost all tissues and under many circumstances. Normally the cell division is regulated by a family of extracellular growth factors that cause resting cells to divide and in some cases, differentiate. A precise balance is always maintained between cell proliferation and programmed cell death and both the phenomenon are highly regulated by growth and necrosis factor to ensure the integrity of organs and tissues. Defects in the synthesis, regulation or recognition of growth factor can lead to cancer. The progression from normal cell to a malignant tumour requires an accumulation of mutations (sometimes over several decades), none of which, alone, is responsible for the end effect. For example, the development of colorectal cancer has several recognizable stages, each is associated with mutations. Phase-I metabolizing enzymes (Cytochrome P_{450}) play an important role in the initiation of cancer through the catalytic activity of enzymes. A polar reactive group is associated to lipophilic carcinogen xenobiotics to form electrophile react with DNA, later xenobiotic components can be detoxified by the Phase-II metabolizing enzymes with sugar, amino acids and glutathione.

Tea polyphenols can interact with enzymatic defense mechanism in cells and contribute to cancer prevention at early stage of carcinogenesis (Yang 1997). Conjugation and subsequent inactivation of carcinogen by Epigallocatchin Gallate mediates through the inhibition of phase-I enzymes and corresponding activation of phase-II enzymes (Katiyar *et. al.* 1996). The flavonoids present in green and black tea help to sustain normal cell growth by blocking the activation of oncogen AP-I (Activator Protein), maintaining cell-cell communication and increasing apoptosis of malfunctioning cells (Marian 2004).Lipid peroxidation is also associated with some phases of carcinogenesis. DNA adducts like deoxy-adenosine and deoxy guanosine are directly induced by malondialdehyde, the end product of lipid peroxidation. In vitro study reveals that different tea polyphenols can effectively inhibit malondialdehyde generation in tissue system. The heterocyclic amines formed during cooking of proteinaceous animal food can induce lymphoma, colon and prostate tumor by DNA adducts formation in various organs and tissues. It is reported that both green and black tea exhibit potential chemo preventive property against heterocyclic amine induced tumorogenesis in rat model.



Possible routes of cancer prevention by tea polyphenols

Tea poly phenols regulate Cardiovascular and cerebrovascular diseases: - Now a day heart failure due to occluded coronary arteries is a leading cause of death in industrial society. Atherosclerosis or obstructions of blood vessels are linked to high level of cholesterol in blood and particularly high level of LDL bound cholesterol. Complexity of atherosclerosis and the risk of coronary artery diseases is increased manifold due to simultaneous association of hypertension, diabetes mellitus, hyperlipidimia and excess blood level iron. All the above ailments can be effectively controlled by tea polyphenols.

The ability of polyphenolic compounds to offer cardiovascular system protection has also stimulated efforts to investigate whether these compounds may offer neuroprotective effect (Gross 2004). Lipid peroxidation of biological membrane is particularly associated with degeneration of synapses and neurons which may be observed in neuronal disorder like Alzheimer, Parkinson and Huntington diseases. The pathological presentation of Alzheimer diseases involves regional neuronal necrosis and accumulation of intra and extra neuronal lesions. It is clear from several research findings that tea polyphenols can reduce the risks of neuro-degenerative diseases during older ages.

Tea polyphenol and Soil Environment:

Polyphenol rich plant communities have occurred on highly acidic and infertile soils through out the world. Many 'negative feedbacks' have been identified whereby plant degrade fertile soils through production of polyphenol-rich litter, sequestering soil nutrient into unavailable form and creating unfavourable conditions for seed germination, root growth, and nutrient uptake. But in the context of plant–litter soil interactions in ecosystems adapted to soils that are inherently acidic and infertile, there are also many 'positive feedbacks' that result from polyphenol production. By inhibiting decomposition, polyphenols regulate the formation of a mor-humus litter layer, conserving nutrients and creating a more favorable medium for root growth. Polyphenols shift the dominant pathway of nitrogen cycling from mineral to organic forms to minimize potential N losses from the ecosystem and maximize litter-N recovery by mycorrhizal symbionts. Polyphenol complexation of Al, Mn and Fe reduce potential Al toxicity and P fixation in soil. Polyphenols regulate organic matter dynamics, leading to the accumulation of organic matter with cation exchange capacity to minimize leaching of nutrient cycling.

Conclusion:-

Tea industries have created potential domain of economy and nearly 5 lakhs people is now dependant, directly or indirectly, on cultivation, production and marketing of tea products only in North Bengal. A cup of tea is now considered to be the golden ore of herbal medicine which can protect several critical and emerging stress induced vascular diseases and even cancer. An all time honest effort from every corner of the society and intensive researches are required to enhance the quality and quantity of tea products and their versatile uses in therapeutics. Judicious use of high end agronomic practices should also be maintained in tea farming to ensure the sustainability and productivity in long run.

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