Theme-3.2- Food and Pharmaceuticals

Therapeutic Potential of Bamboo Shoots against Cancer: An Overview

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Abstract

Cancer, the feared non-communicable disease, contributes a staggering 16% to total deaths worldwide. Despite the enormous advances in medical research, cancer continues to pose an impregnable challenge for global health care systems with its massive economic burden mounting to approximately US$ 1.16 trillion. However, about 30-50% cases of cancer remain preventable mainly through modification of our dietary patterns. Over the years it has been scientifically proven that plant based diet exert preventive and antagonistic effects on cancer incidences. These whole plants and other natural plant products have a plethora of bioactive phytochemicals embedded in them which actively functions towards prevention and treatment of varied cancer forms. Moreover, plant based cancer prevention therapy is considered safe largely because it lacks the side effects normally associated with other cancer treatment strategies like chemotherapy and radio therapy *etc*. Bamboo shoots, the highly palatable juvenile culms of bamboo plant which have proven nutritional credentials, possess rich repositories of several phytochemicals like phenolic compounds, dietary fibres, phytosterols and several other functional groups which are known to possess anti-cancerous properties. With its worldwide distribution, bamboo shoots represent a vast natural resource which can very effectively be promoted as a potential functional food in the form of a highly efficient, healthy and economic anticancer therapeutic system.

Key Words

Cancer prevention, Bamboo shoots, Phytochemicals, Phenols, Phytosterols, Dietary fibre

Introduction

Cancer, a pathological condition characterized by the rapid, abnormal, uncontrolled and proliferative growth of the body cells, is the most feared causes of morbidity and mortality worldwide claiming approximately 8.8 million lives in 2015 alone. It contributes 16% to global deaths, making it second most deadly diseases after cardio vascular diseases with 32% of total deaths (WHO 2017). Despite the enormous advances in medical research, complete treatment of an advanced stage of cancer is still elusive, a problem aggravated by late diagnosis of several cancer types. Further, apart from the

obvious physical and psychological sufferings any new cancer diagnosis unleashes on patients and their family and friends alike, there is also a huge economic predicament associated with cancer treatment which is particularly harsh for less resourceful and economically weaker sections of society. The total annual economic burden of cancer was estimated to be whopping US$ 1.16 trillion and most of this expenditure was incurred on the treatment alone. This social and economic burden of cancer can be curtailed to a bare minimum if we can direct our efforts and resources more towards blocking the cancer at its inception *i.e.* towards prevention rather than treatment. It has been estimated that of all the cancer related deaths, around 30-50% were preventable as they were caused by various behavioral and dietary risk with most prominent being a low fruit and vegetable intake in the diet (Doll and Peto 1981; Stewart and Wild 2014). Thus, it is clear that prevention by modification of our dietary patterns could be the most efficient, long term and cost effective strategy of curtailing this growing menace of cancer. Reflecting the protective action of plant based diet, consumption of at least five or more servings of fruit and vegetables per day has been recommended for the prevention of several chronic diseases including cancer (NRC 1982; WHO 2013). As such, regular consumption of a plant based diet having higher proportions of fruit and vegetables have been shown to prevent onset of several cancer types particularly cancers of lung, oesophagus, oral cavity, larynx, pancreas, stomach, colorectal, bladder, cervix, ovary, endometrium and breasts (Block *et al*. 1992; Liu 2003; Aune *et al.* 2011; Aune *et al.* 2012; Jung *et al*. 2013; Liu *et al*. 2013; Yao *et al*. 2014; Ben *et al*. 2015; Vieira *et al*. 2015a,b; Wang *et al*. 2015a,b). Several scientific studies have proved empathetically that these preventive actions of fruit and vegetables based diet on cancer incidents is mainly because of diverse array of bioactive phytochemicals embedded in them (Giovannucci *et al*. 2002; Joseph *et al*. 2004; Sun *et al*. 2007; Pierce *et al*. 2007; Park *et al*. 2008; Shu *et al*. 2009; Rodríguez-Ramiro *et al*. 2011; Hu *et al*. 2012; Song *et al*. 2012; Benim *et al*. 2013). Plants contain a wide variety of bioactive phytochemicals such as phenols, phytosterols, dietary fibre, carotenoids, flavonoids, lectins, organosulfur compounds, glycosides and countless other bioactive compounds which shows anti-cancerous properties with their distinguished mechanism of action. However, administration of such phytochemicals individually, in purified and/or fortified forms has so far failed to show desired positive correlation on the reduction of cancer risks or even found to increase the risks of cancer incidences as per some clinical investigations (Omenn *et al*.1996; Bjelakovic *et al*. 2004; Myung *et al*. 2009; Bjelakovic *et al*. 2014). This suggests that these phytochemicals, being present in fruit and vegetables in a mosaic with varied concentrations, do not exert their preventive action against a specific cancer type individually but rather act synergistically to prevent consumers from several cancer types in a holistic manner. Amidst of all this, one thing which is almost certain is that regardless of their specific mechanism of action, consumption of plants foods and food products rich in such phytochemicals is highly beneficial toward the alleviating the risks of cancer. As a result, popularization of plant based foods as a healthy dietary alternative has shot up several notches in recent years and researches are always working tirelessly to identify such novel plant sources having

rich phytochemical profiles that can contribute toward our continued fight against this evil of cancer. Bamboo shoots have emerged as one such novel food resource which possesses several highly bioactive phytochemicals with potent anti-cancerous properties. Along with its superior organoleptic and nutritional qualities and easy availability throughout world, bamboo shoots have all the necessary ingredient to be regarded as a functional food consumption of which can impart protection from cancer in a highly efficient and cost effective manner. This article describes in detail the major phytochemicals of bamboo shoots having anti-cancerous properties along with their plausible mechanism of actions. Scientific studies confirming the anti-cancer actions of shoots are also discussed.

Bamboo Shoots

Bamboo, which is mainly an evergreen and perennial plant belonging to subfamily Bambusoideae under monocotyledonous family Poaceae, possesses a well-developed underground rhizome system which bears vegetative buds that grow outwards to form aerial culms. These emerging, actively growing and tender culms are termed as bamboo shoots. The rapid emergence of the bamboo shoots from the underground rhizome system often coincide with the onset of rainy season when the temperature and moisture conditions are most optimum for the growth of shoots. These tender culms or shoots contains an inner core of soft edible tissue. This soft, white to pale-white edible portion of the shoots is covered with protective non-edible, overlapping leaf sheaths or culm sheaths, which need to be removed to obtain edible portion (Kleinhenz *et al*. 2000). Bamboo shoots has always been an integral part of traditional culinary baskets of local communities in East and Southeast Asia of countries like Japan, China, Korea, India, Indonesia, Thailand *etc*. and now with the backing of scientific evidences, bamboo shoots have made a distinct niche for themselves in global food markets with their superior nutritional repositories (Park and Jhon 2009; Nirmala, *et al.* 2011; Sood *et al*. 2013; Badwaik *et al*. 2015; Mahayotpanya and Phoungchandang 2016, Saini *et al*. 2017). Table 1 shows the nutrient composition of young shoots of few bamboo species analyzed in current study. Although, out of about 1500 existing species, around 200-500 species produce shoots of edible quality, but only less than 100 species are most commonly used for their edible shoots worldwide (Maoyi and Baniak 1995; Hazra 2007). Consumption of bamboo shoots has been linked with several health benefits more importantly with the prevention of several chronic diseases such as metabolic disorders, cardiovascular diseases and certain types of cancers and the scientific basis of their natural preventive action has been attributed to the presence of bioactive compounds in the shoots (Nirmala *et al*. 2014).

Table 1:- *Macronutrients (g/100g) and Vitamins (mg/100g) content in fresh and shoots of few bamboo species.

Species	Carbohy-drate	Starch	Amino Acid	Protein	Fat	Moisture	Ash	Vit C	Vit E
Bambusa tulda	3.24±0.04	1.18±0.02	1.89±0.02	3.14±0.03	0.46±0.01	82.91±2.32	0.92±0.12	2.43±0.03	0.57±0.01
Dendrocalamus giganteus	4.52±0.06	1.68±0.01	2.41±0.01	3.97±0.02	0.34±0.02	83.54±1,21	0.86±0.23	2.81±0.03	0.59±0.01
D. latiflorus	3.43±0.16	0.91±0.04	2.19±0.16	3.45±0.08	0.43±0.01	88.74±0.89	0.79±0.11	2.37±0.04	0.52±0.01
D. membranaceous	3.74±0.04	1.04±0.12	2.15±0.13	3.79±0.03	0.37±0.01	88.26±0.92	0.83±0.09	2.63±0.03	0.49±0.02

*Source-Current Study, ± represent standard deviation of data set from the mean sample.

Phytochemicals in Bamboo Shoots and Their Anti-cancerous Properties

Bamboo shoots contain several phytochemicals which have been proven to have potent anti-cancerous properties such as phytosterols, phenols and dietary fibres. These phytochemicals and their cancer protective effects have been discussed here as below:-

Phytosterols

Phytosterols are C28 and C29 carbon steroid alcohols of plant origin. These chemicals bear structural resemblance to cholesterol, differing only on the basis of presence or absence of double bonds and/or length of carbon side chains and type of attached functional groups. Being structurally related to cholesterol, phytosterols also perform same function in plant cells as performed by the cholesterol in the animal cells which is stabilization of phospholipid bilayer of plant cell membranes. Phytosterols are either present in bounded esterified form within plant cell membranes or occur freely in the cytoplasm. They may exist either in original sterol form or their saturated counterparts known as stanols. So far more than 200 different types of phytosterols have been reported to exist in the plants but the most abundantly and commonly found phytosterols present in edible plant foods includes β-sitosterol, campesterol, and stigmasterol (Lagarda *et al.*, 2006). As these compounds cannot be synthesized by humans thus their only natural source is plant based diet such as vegetable oils, seeds, nuts and legumes. Phytosterols have gained lots of acclaim in the recent times due to their potential implications for human health. Emergence of scientific evidences supporting their beneficial action on reducing serum cholesterol and low density lipoprotein (LDL) cholesterol levels and reducing blood cholesterol levels have resulted in promotion of phytosterols rich plant based diets (Jones *et al*. 1997; Plat and Mensink 2005; Jones and AbuMweis 2009). As they are structurally similar to cholesterol they compete with cholesterol for absorption in small intestine thus causing its removal from the gut (Varady *et al*. 2007). Additionally, phytosterols have also been shown to modify the activity of

several intestinal membrane-transport proteins linked with cholesterol movements across the cells thereby reducing the serum cholesterol levels (Marinangeli *et al.* 2006; Jones *et al*. 2007). However, apart from their cholesterol lowering activities, several epidemiological studies have shown phytosterols to possess potent anti-cancerous properties against major cancer types such as of the lung cancer, stomach cancer, ovary cancer and estrogen-dependent human breast cancer. Mendilaharsu *et al*. (1998) during a case control study involving 463 patients with recently diagnosed lung cancer and 465 controls, found that consumption of phytosterol rich diet led to a 38-50% reduction in lung cancer development. Similarly, De Stefani *et al*. (2000) reported an inverse relationship between phytosterols consumption and risk of gastric-cancer during a case control study involving 120 patients diagnosed with stomach cancer, and 360 controls. McCann *et al*. (2003), while working with female patients diagnosed with ovarian cancer, reported that higher than 23 mg/day consumption of stigmasterol led to successful reduction in development of ovary cancer. These epidemiological studies have been supported by several clinical investigations involving model animal systems which successfully demonstrated the preventive role of phytosterols consumption on the incidences of several cancer types. Raicht *et al.* (1980) while investigating the effect of dietary phytosterols on the growth of methylnitrosourea induced colon tumor in rats found that when rats were fed with a diet having 0.2% β-sitosterol for 28 weeks, the number of rats developing colon tumor reduced by 39% along with a 60% reduction in the number of tumors per rat. Dreshner *et al*. (1982) found that inclusion of β-sitosterol in the diet of rats fed with colon cancer inducing chemical carcinogens such as methylnitrosourea, caused a reduction in cell proliferation. Similarly, Awad *et al.* (1997) found that rats fed with a diet containing 1–2% phytosterol mixture (56% β-sitosterol, 28% campesterol, 10% stigmasterol and 6% dihydrobrassicasterol) for 22 days showed a reduction in proliferation of the cholic acid–induced hyperproliferated colonocytes thereby suggesting that dietary phytosterols can prevent the development of chemically induced colon cancer. Similarly, other clinical studies have confirmed the preventive effect of dietary phytosterols against prostate cancer (von Holtz *et al.* 1998) and breast cancer (Downie *et al*. 1999; Awad *et al*. 2000; Ju *et al*. 2004). Several mechanisms of actions have been proposed by which phytosterols might be exerting their anit-cancerous abilities including inhibition of carcinogens like reactive oxygen species (ROS), inhibition of metastasis, slowing down of cell cycle progression, inhibition of angiogenesis, invasion and adhesion of cancer cells and inducing apoptosis (Vivancos and Moreno 2005; Choi *et al.* 2007; Awad *et al*. 2007; Moon *et al*. 2007; Park *et al*. 2007). These integrated mechanisms of action of phytosterols toward inhibition of cancer are depicted in Figure 1 (Woyengo *et al*. 2009).

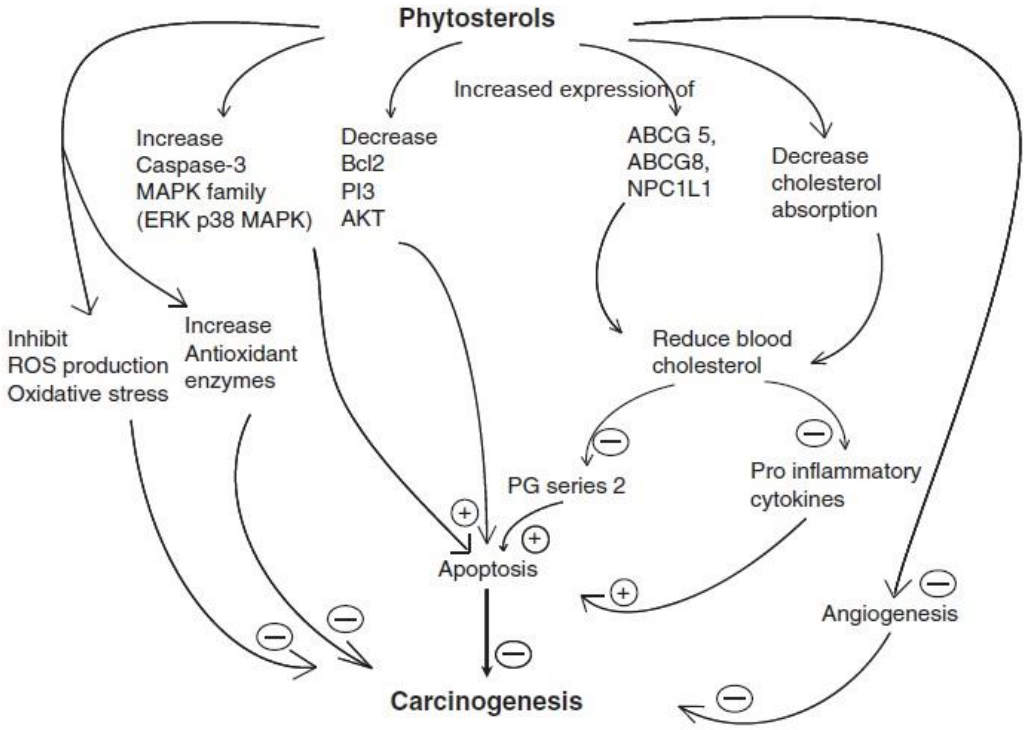

Figure 1- Proposed mechanisms of action of phytosterols on carcinogenesis.* **Woyengo *et al*. 2009**

These epidemiological and clinical studies thus signify the importance of including phytosterols rich foods in our diets. Bamboo shoots have been found to contain appreciable amount of phytosterols in previous studies and their high phytosterols levels is also confirmed in the current study (He and Lachance 1998; Lu *et al*. 2009; Zheng *et al*. 2014, Rawat *et al*. 2016) (Table 2). Major types of phytosterols identified in bamboo shoots include β-sitosterol, campesterol, stigmasterol, ergosterol, stigmastanol, stigmasta-3,5-dien-7-one, stigmast-4-en-3-one (He and Lachance 1998; Lu *et al*. 2009) (Figure 2). Phytosterols from bamboo shoots have already been proved to have several health benefits including reduction of serum cholesterol, anti-microbial activity and prevention of chronic non-bacterial prostatitis (Lachance and He, 1998; Lu *et al*. 2011; Tanaka *et al*. 2013). Therefore all these health benefits coupled with potent anti-cancerous properties of phytosterols embedded in shoots, makes bamboo shoots an exciting prospect for developing future nutraceuticals.

Dietary Fibre

Components of edible plant foods, which are mostly non-digestible in human gastrointestinal tract and are either water soluble or insoluble, have traditionally been referred to as dietary fibre collectively and include polysaccharides such as cellulose, hemicellulose, pectin, gums, mucilages and lignin (Rao 2003). More recently oligosaccharides such as inulin and resistant starches have also been included in the broad ambit of dietary fibre (Jones *et al*. 2006). Consumption of food or food products rich in dietary fibre content has been shown to be beneficial in improving digestive function, reducing serum cholesterol levels, normalizing blood sugar levels, easing constipation, prevention of diabetes, obesity

and chronic heart disease (Chen and Anderson 1979; Fernandez 2001; Merchant *et al*. 2003; Anderson 2008). Dietary fibre lower serum cholesterol levels by reducing the absorption of dietary cholesterol, inhibiting cholesterol synthesis by hepatocytes and forming complexes with bile acids which have cholesterol as their major component thereby reducing the free cholesterol from the pool (Chen and Anderson 1979; Fernandez 2001). Further, soluble component of dietary fibre also reduces the glycemic index of food and increases insulin sensitivity thereby is helpful in the prevention and treatment of type 2 diabetes (Zhao *et al*. 2002). Apart from its positive influence on cholesterol reduction and regulation of bowl movements, dietary fibre have been heavily linked with the reduction in cancer risks particularly the colorectal, breast, mouth, throat and esophageal cancer (Bagga *et al*. 1995; Soler *et al*. 2001; Zeng *et al*. 2014). Several epidemiological studies have found a strong correlation between a high fibre diet with the reduced risks of colon or colorectal cancer. Burkitt (1971) linked the high dietary fibre intake with a low incidence of colorectal cancer in most populations of Africa and other under developed countries. A review of 37 observational epidemiologic studies and meta-analyses data from 23 case-control studies indicated a strong relationship between high fibre diet intakes with the lower risks of colon cancer (Trock *et al*. 1990). In another study it was found that a consumption of more than 27 g of fibre per day led to 50% reduction in the risk of colorectal cancer as compared to the consumption of diet having less than 11g of fibre per day (Howe *et al*. 1992).

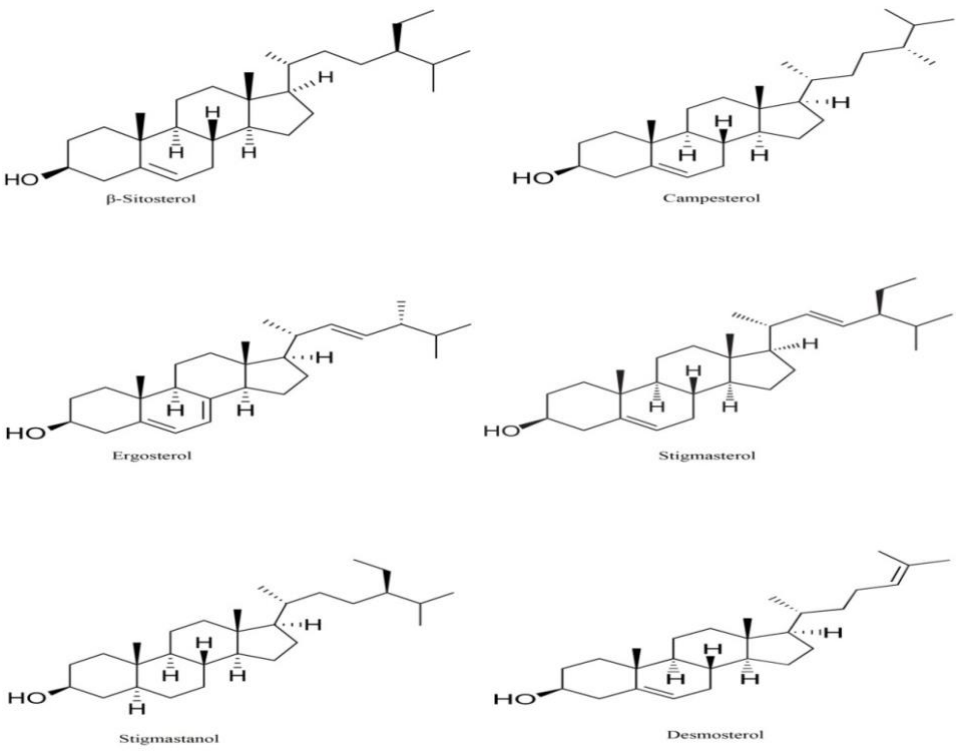

Figure 2-Some of the major phytosterols found in bamboo shoots.

Thun *et al*. (1992) in a large prospective study involving more than 1 million subjects, showed a significant inverse relationship with a 30% reduction of colorectal cancer deaths in subjects consuming the highest amount of dietary fibre compared with those consuming the lowest amount. Similarly, an analysis of 28 correlation studies examining the relationship between dietary fibre consumption and risks of colorectal cancer in the populations found that almost 82% studies showed positive influence of dietary fibre intake on the reduced incidences of colorectal cancer (Kim 2000). Peters *et al.* (2003) in a large study involving more than 3500 adenoma cases (precursor of colon carcinogenesis) found that risk of distal adenoma decreased with higher intake of dietary fibre by about 27% in both men and women. Nomura *et al*. (2007) in a multi-ethnic cohort study involving 85,903 men and 105,108 women, found that higher dietary fibre intake was inversely linked to the colorectal cancer risk in men, but had no or limited effect in women.

Several mechanism of action by which dietary fibre exert positive effect on reduction of colon cancer have been proposed which include reducing the digestion and absorption of macronutrients and decreasing the contact time of carcinogens within the intestinal lumen, production of short chain fatty acids such as butyric acid which promote the growth of healthy gut microflora and by promoting apoptosis (Figure 3) (Zeng *et al*. 2014).

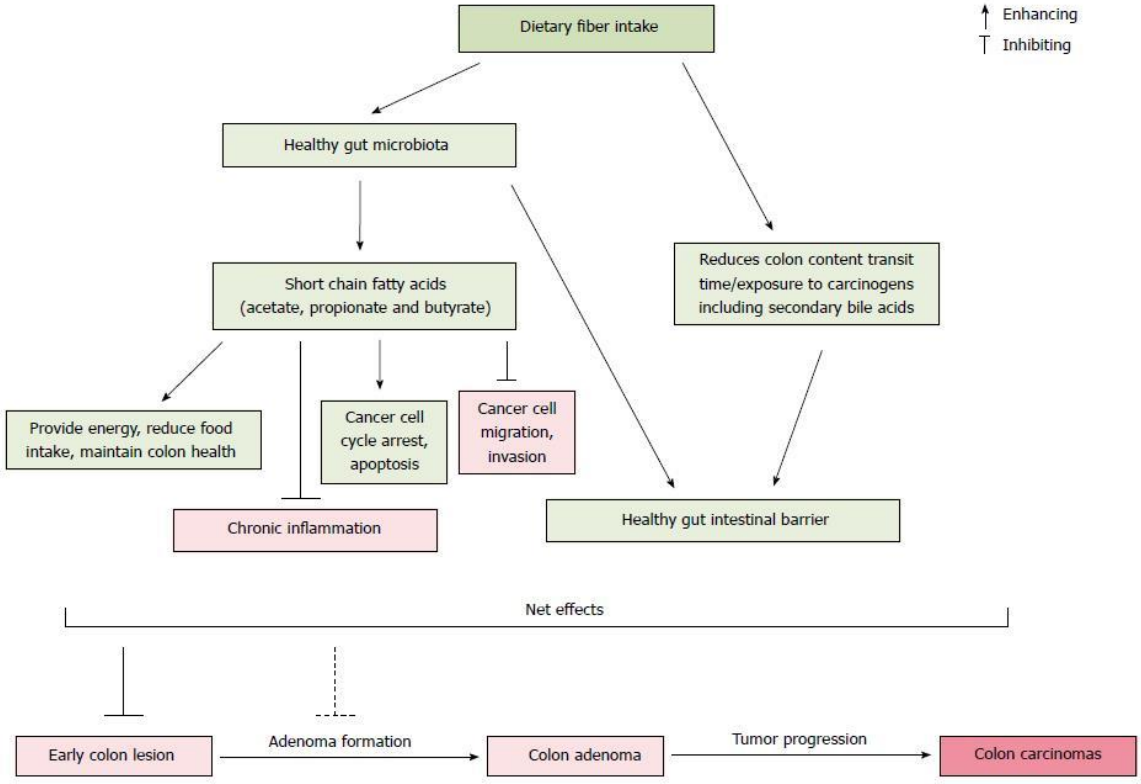

Figure 3- Proposed mechanism of action of dietary fibre against colon carcinogenesis. ***Zeng *et al.* 2014.**

Intake of high fibre diet has also been linked with lower incidence of breast cancer, probably by binding to and removing excess of estrogen, a potent carcinogen from the system (Soler *et al*. 2001). Consumption of fibre rich diet has also been linked with reduction in the incidences of mouth, throat, esophageal, and prostate cancer probably by limiting the contact of carcinogen with the mucosal membrane and promoting the antioxidant mechanism of body (Bagga *et al*.1995). Bamboo shoots contain significant dietary fibre content as reported in current study and by several previous investigations (Ferreira *et al.* 1992; Bhatt *et al*.2005; Kumbhare and Bhargava 2007; Nirmala *et al.* 2007) (Table 2). Dietary fibre from bamboo shoot have been shown to impart several health benefits including prevention of intestinal diverticulum and hyperlipemia (Naito *et al.* 1980); improvement in bowl movement (Shimizu *et al.* 1996); relieving constipation (Anping 2005) and improvement in fecal volume, bowel movement frequency and reduction in cholesterol (Park and Jhon 2009). Bamboo shoots as a dietary fibre source thus have direct beneficial effects on lipid profiles and bowel functions with positive implication on cardiovascular health of the consumers. Additionally, high cellulose content of bamboo shoots have been linked with promoting the gut microbial flora and improving the peristalsis of intestine which could prevent intestine cancers (Shi and Yang 1992).

Table 2:- *Bioactive compounds Phenols (mg/100g), Phytosterols (mg/100g) and Dietary Fibres (g/100g) in fresh shoots of few bamboo species.

Species	Phenols	Phytosterols	Dietary Fibre
Bambusa tulda	473.75 ±2.01	94.75±0.31	4.62 ±0.01
Dendrocalamus giganteus	608.00 ±2.19	156.00±0.41	5.82 ±0.02
D. latiflorus	767.00 ±1.94	64.25±0.05	5.80 ±0.02
D. membranaceous	595.00 ±1.84	161.00±0.13	5.01 ±0.04

*Source-Current Study, ± represent standard deviation of data set from the mean sample.

Phenolic Compounds

Phenols include a large group of diversified secondary metabolites produced mostly *via* shikimate, phenylpropanoid, flavonoid, anthocyanin, and lignin pathways. Structurally, all the phenols are simple aromatic hydrocarbons having either one (phenol) or more than one hydroxyl group substitution (polyphenols). Major group of plant phenolic compound includes flavonoids (flavones, flavonols, anthocyinidin, isoflavones *etc*.); tannins; chalcones; coumarins and phenolic acids (Giada 2013). Phenolic compounds signify the largest groups of natural antioxidant mainly because of the strong hydrogen-donating properties of their hydroxyl groups. They prevent the oxidative damage of various biomolecules such as DNA, lipids and proteins by scavenging various reactive species such as superoxide radical, hydroxyl radical, peroxyl radical,

hypochlorous acid, and peroxynitrous acid and also by chelating metal ions thus playing an important role in prevention of various chronic diseases such as cardiovascular diseases, gastric ulcers, (Puupponen-Pimiä *et al.* 2001; Mira *et al.* 2002; González-Gallego *et al.* 2007; Landet 2012; Saliu *et al.* 2012). However, the health benefit which has attracted the strongest interest of researchers during past few decades is their anti-cancerous property, probably owing to their strong anti-oxidant nature. Several epidemiological studies have confirmed the positive effect of phenols on the reduction of several cancer types. Knekt *et al*. (1997) in a prospective study involving 9959 men and women in Finland, found an inverse relationship between the intake of flavonoids and incidence of cancer with up to 50% reduction in development of lung cancer after highest flavonoid intake. Consumption of quercetin extracted from onions and apples was found to be beneficial against lung cancer and squamous-cell carcinoma (Marchand *et al*. 2000; Boyle *et al*. 2000).

Phenolic acids such as caffeic acid, ferulic acid, gallic acid and protocatechuic acid *etc*. found in grape extracts and wine has been reported to exert anti-cancerous activity against various types of cancer such as breast, lung, and gastric cancer (Stagos *et al*. 2006). Faried *et al.* (2007) studied the anticancerous properties of gallic acid extracted from Indonesian herbs, and reported that as a natural antioxidant, gallic acid had significant inhibitory effects on cell proliferation and induced apoptosis in several cancer cell lines along with higher selective cytotoxicity. Chlorogenic acid and caffeic acids were found to inhibit the formation of mutagenic and carcinogenic N -nitroso compounds *in vitro* (Han *et al*. 2007). Chlorogenic acid from coffee was also found to inhibit the formation of DNA single strand breaks and dinitrogen trioxide by scavenging nitrogen dioxide generated in the human oral cavity thereby exerting anti-cancerous activity against several cancer types (Takahama *et al*. 2007). Caffeic acids, capsaicin, and gingerol (an analog of phenolic acids) showed anti-cancerous activity by modulating the ceramide-induced signal transduction pathway, suppressing the activation of NF-κB and AP1 activty, and inhibiting the protein tyrosine kinase (PTK) activity (Surh 2003; Han *et al*. 2007; Johnson 2007). Farina *et al*. (2006) reported the potent angiogenesis inhibition and antitumor activity of genistein, a soy isoflavone against melanoma and breast cancer in a mouse model. Several mechanisms of action of phenolic compound against carcinogenesis have been proposed including promotion of antioxidant activity; modulation of carcinogen metabolism; regulation of gene expression; promotion of apoptosis; inhibition of signal transduction pathways including nuclear factor kappa light chain enhancer of activated B cells (NF-κB), activator protein-1 (AP-1), mitogen-activated protein kinases (MAPK), and suppression of angiogenesis (Huang *et al*. 2009; Rosa *et al*. 2016) (Figure 4).

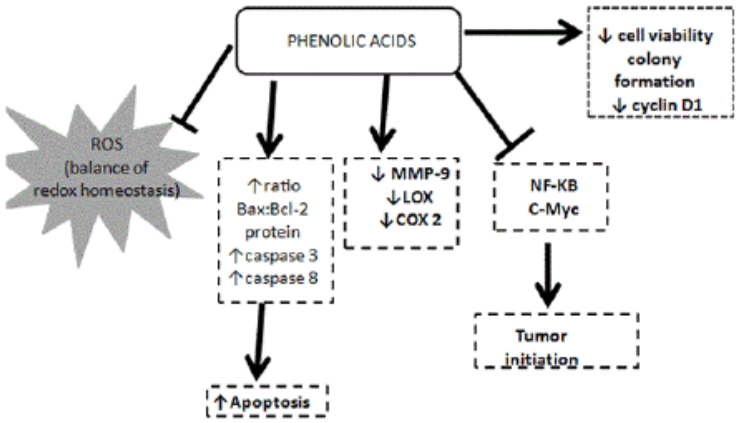

Figure 4-Mechanism of anti-cancer activity of phenolic compounds. ***Rosa *et al*.2016.**

Bamboo shoots are considered a rich source of phenolic compounds and at least 25 individual phenolic compounds has been identified in the shoots using GC-MS analysis such as 5-dihydroshikimic acid, shikimic acid, p-hydroxyphenylethanol, p-hydroxyphenylpropionic acid, ferulic acid, caffeic acid, chlorogenic acid, protocatechuic acid, p-hydroxybenzoic acid, catechin, syringic acid, gallic acid, vanillic acid, p-coumaric acid, and ferulic acid (Figure 5) (Kozukue *et al.*1998; Park and John 2010; Pandey and Ojha 2013; Bajwa *et al*. 2015; Rawat *et al*. 2016) and presence of significantly high amounts of phenols in shoots has been confirmed in current study (Table 2). Several investigations has reported that bamboo shoot extract possess potent antioxidant properties which is correlated to their phenolic content (Park and John 2010; Badwaik *et al*. 2014; Badwaik *et al*. 2015).

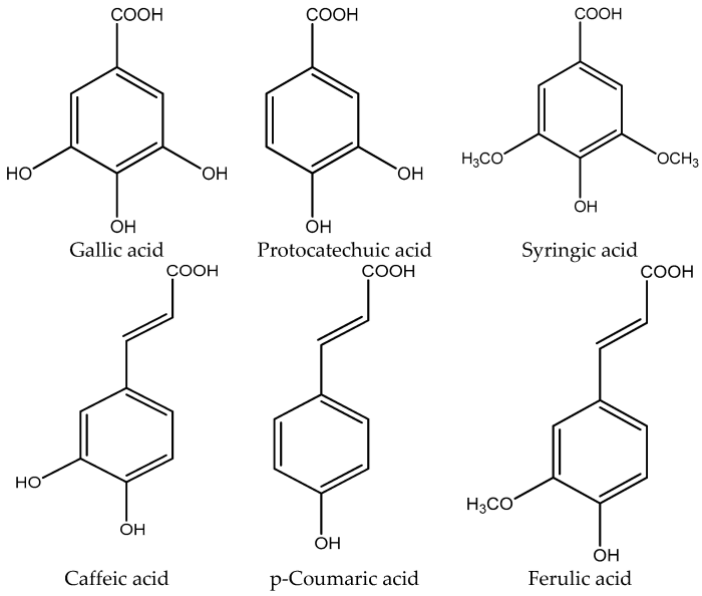

Figure 5-Major phenolic compounds identified from bamboo shoots.

Other Phytochemicals from Bamboo Shoots and Their Anti-cancerous Properties

Apart from phenolic compounds, bamboo shoots also contain significant quantities of other potent antioxidant compounds such as Vit C and Vit E (Table 1) which are involved in the prevention of several cancer types such as breast, oral, gastric, esophageal, pancreatic, lung, cervical, and rectal cancer (Byers and Guerrero 1995; Block 1991, Lonn *et al*. 2005). Bamboo shoots are also a rich source of selenium (Se), an essential mineral element which plays a key role in the cellular metabolism (Saini *et al.* 2017). Se is an integral part of major antioxidant enzymes of human body such as glutathione peroxidase (GPx), thioredoxin reductase (TrxR) and iodothyronine deiodinases (IDD) and other selenoproteins. Because of its strong anti-oxidant activity, Se has been linked with prevention of several cancer types such as prostate, colon and lung cancer (Clark *et al*. 1996; Yoshijawa *et al*. 1998). Another group of phytochemicals from bamboo shoots with potent anti-cancerous properties include glucosinolates. Chemically, glucosinolates are thioethers containing β-D-thioglucose linked to an organic aglycone via an ester bond. Hydrolysis of glucosinolates yields isothiocyanate, nitrile and thiocyanate. So far around 100 glucosinolates have been characterized in plants where they play a role in herbivore defense mechanism (Sorenson 1991). Although believed to be interfering in thyroid metabolism upon their consumption, several recent scientific evidences have linked the glucosinolates and their hydrolysis products against carcinogenesis of several cancer types such as cancers of the colon, rectum and thyroid (Wattenberg 1989; WCRF 1997; Hecht 1999; Shapiro *et al*. 2001; Hayes *et al.* 2008; Fahey *et al*. 2012). Glucosinolates and their hydrolysis products especially isothiocyanates act in prevention of carcinogenesis in several interconnected mechanisms including induction of phase-II detoxification enzyme and promotion of apoptosis (Melchini and Traka 2010) (Figure 6).

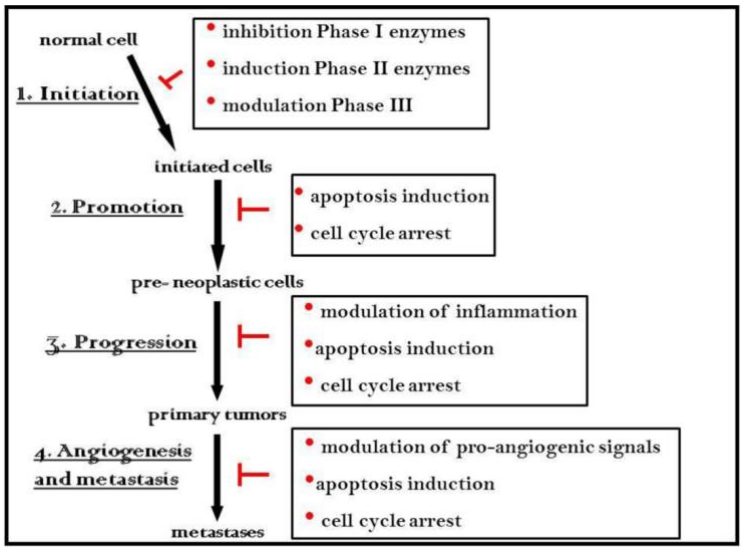

Figure 6-Mechanism of action of isothiocyanates against carcinogenesis ***Melchini and Traka 2010**

Bamboo shoots have been reported to contain small but detectable quantities of glucosinolates which can be utilized for their potent anti-cancerous properties (Chandra *et al.* 2004). Current study also reveals presence of significant quantities of glucosinolates in bamboo shoots (Table 3). Similarly, another group of antinutrient compound from bamboo shoots *i.e*. saponins, the polycyclic aglycones, has also been shown to possess anti-cancerous activity particularly against the incidences of colon cancer (Ellington *et al*. 2005). There have been some previous reports which detected and quantified the saponin content of bamboo shoots (Singh *et al*. 2012; Sarangthem and Singh 2013). Current study has also found significant quantities of saponins in the shoots (Table 3).

Table 3-Glucosinolate and saponin content (mg/100g) in fresh shoots of some bamboo species.

S**pecies**	Glucosinolates	Saponins
Bambusa tulda	29.11±1.18	228.43±3.32
Dendrocalamus giganteus	26.33±0.92	232.21±2.22
Dendroclamus latiflorus	25.41±0.87	241.39±2.46
Dendroclamus membranaceous	26.99±0.77	246.03±4.09

*Source-Current Study, ± represent standard deviation of data set from the mean sample.

Clinical Studies Confirming Anti-cancerous Properties of Bamboo Shoots

Hiromichi (2007) successfully tested the antitumor effects of ethanol extract of several bamboo species (*Phyllostachys pubescens*, *Phyllostachys nigra* var. henonis. *Phyllostachys bambusoides, Pseudosasa japonica, Pleioblastus simonii,* and *Gigantochloa apus)* against malignant tumors (Malignant sarcoma cells and Ascites tumor cells) in a mice model system. An alcoholic extract was administered to cancer induced BALB/c mice. Tumor growth was suppressed without impairing body growth demonstrating an excellent anti-tumor activity. Other than shoots, clinical studies have also confirmed the potent anti-tumor properties of other parts of bamboo plant such as leaves and culms. Panee (2008) reported that ethanol and water extract prepared from small branches and leaves of *Phyllostachys edulis* can inhibit the development of chemically induced breast cancer as indicated by the inhibition of high-fat diet induced weight gain, inhibition of hyperinsulinemia, and significant reduction in the circulating levels TNF-α in high fat- diet treated mice. Lu *et al*. (2010) investigated the anti-tumor activity of extracts of stem shavings of *Phyllostachys nigra var. henonis* and found that bamboo shaving extract showed potent antitumor activity against mouse leukemia (P388) and human

lung adenocarcinoma (A549) cell lines in sarcoma-loaded mice S180 model systems . They also isolated 'friedelin', a triterpenoid monomer as the main active component of bamboo shaving extract using CO_2 supercritical fluid extraction (SFE) technique. The isolated 'friedelin' also exhibited strong antitumor activity against human melanoma (A375), mouse lung epithelial tumor (L929), human cervical tumor (Hela) cells and human macrophage tumor (THP-1) cell lines. Seki *et al.* (2010) found that hot water extracts prepared from the leaves of *Sasa senanensis* exhibited potent antitumor activity against K562 cells (human chronic myeloid leukemia) and YAC-1 cells (murine lymphoma) cell lines maintained in several mice modals as indicated by suppression of tumor growth, prolongation of life and promotion of macrophages and human natural killer cells (NK) in tumor bearing mice. Kim *et al.* (2013) reported that volatile extracts of *Phyllostachys bambusoides*, *Phyllostachys pubescens* and *Phyllostachys nigra var. henonis* possesses significantly high antioxidant activity and successfully inhibited tumor growth in prostate cancer PC-3 cell lines. Recently, Patil *et al*. (2017) evaluated the effectiveness of gold nanoparticles (AuNPs) synthesized using *Sasa borealis* leaf extracts as antitumor agents and they found these AuNPs showed good antitumor activity against human gastric adenocarcinoma (AGS) cell lines.

Conclusion

Phytochemicals obtained from natural plant resources have now gained prominence for their use as prophylactic agents in prevention and treatment of several chronic human diseases including cancer which still remains a leading cause of death despite the enormous advances in medical research. Therefore, natural plant products with their plethora of phytochemicals and secondary metabolites are currently viewed as humanities best hope toward prevention and treatment of varied cancer forms largely because they are cost effective and lacks the side effects normally associated with other treatment procedures such as radiotherapy and chemotherapy. Bamboo shoots have been scientifically proven to contain several phytochemicals with significant anti-cancerous properties. Shoots contain high quantities of phenolic compounds which possess potent radical scavenging activity and exert anti-carcinogenic effects by regulating ROS levels, signal transduction cascades, angiogenesis and cell proliferations. Shoots are also a good source of natural phytosterols such as stigmasterol, β-sitosterol and campesterol which provide anti-cancerous effects by inhibition of metastasis, slowing down of cell cycle progression, inhibition of angiogenesis, invasion and adhesion of cancer cells and inducing apoptosis. Dietary fibre from bamboo shoots also possesses anti-cancerous properties. Apart from these major phytochemicals of potential anti-cancerous activity, bamboo shoots also contain several other anti-carcinogenic agents such as glucosinolates and saponins and efficacy of bamboo shoots phytochemicals for their antitumor potential has already been clinically proven. Thus, it is quite evident that bamboo shoots contain diverse arrays of phytochemicals which are highly effective in preventing as well as treating incidences of several types of cancer diseases. Therefore, bamboo,

with its vast worldwide coverage, represent a significant natural resource which has tremendous potential in proving to be one of the best ally in our continued quest to tame cancer. Hence, bamboo shoots should be promoted as a highly efficient functional food and efforts should be made for its inclusion towards any future cancer prevention dietary regimes.

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