



## Tea's Role in health and diseases

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### Abstract

Tea is the most widely consumed beverage in the world. This article discusses its origin, types, processing and chemical constituents. Further, the role of tea in nutrition and its health benefits in various diseases have also been summarized.

**Keywords:** Tea, *Camellia sinensis*, Green Tea, Black Tea, Oolong Tea, White Tea, chemical constituents, health benefits.

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After it has been processed, black tea undergoes a 'Fermentation' process, which lasts for several hours and turns the leaves into a rich copper colour. The bacteria and enzymes, which naturally occur in the leaves change the chemical composition of the tea. Once the fermentation process has come to an end, the leaves are then 'Fired'. This process involves exposing the leaves to hot air and high temperatures. The Firing process actually causes the end of the fermentation cycle by killing the bacteria and enzymes. After firing black tea is ready for consumption. 'Earl Grey', 'English Breakfast' and 'Darjeeling' are some examples of black teas. Black tea is most popular tea in India and the west.

During processing of black tea, the monomeric flavan-3-ols undergo polyphenol oxidase (dependent oxidative polymerization) leading to the formation of bisflavanols, theaflavins, thearubigins, and other oligomers in a process commonly known as oxidation (Subramanian *et al*, 1999). Theaflavins (about 1-2% of the total dry matter of black tea), including theaflavin, theaflavin-3-O-gallate, theaflavin-3'-O-gallate, and theaflavin-3,3'-O-digallate, possess benzotropolone rings with dihydroxy or trihydroxy substitution systems, which give the characteristic colour and taste of black tea. About 10-20% of the dry weight of black tea is due to thearubigins which are even more extensively oxidized

### Introduction

Tea is contemporary world's most widely consumed beverage second only to water with a per capita consumption of 120 mL/day (Vinson & Dabbagh, 1998; Mukhtar & Ahmad, 2000; Katiyar & Mukhtar, 1996). According to Chinese mythology, in 2737 BC the Chinese Emperor, Shen Nung, scholar and herbalist, was sitting beneath a tree while his servant boiled drinking water. A leaf from the tree dropped into the water and Shen Nung decided to try the brew. And thus "TEA" was born. The modern term 'Tea' derives from early Chinese dialect words - such as 'Tchai', 'Cha' and 'Tay' - used both to describe the beverage and the leaf. From the earliest times tea was renowned for its properties as a healthy, refreshing drink (Chopra & David, 2000). Tea, botanically known as *Camellia sinensis* (Linn.) O. Kuntze syn. *Thea sinensis* Linn. is an evergreen plant of the *Theaceae* family.

### Types of tea and chemical composition

Although all tea comes from one species, *Camellia sinensis*, the way in which its leaves are processed gives us four major types of tea, viz. Black Tea, Green Tea, Oolong Tea and White Tea. Of the tea produced worldwide, 78% is black tea, 20% is green tea, and 2% is oolong tea, which is produced mainly in southern China (Yang & Landau, 2000).

#### Black Tea

For processing black tea, the harvested tea leaves are placed on racks where they are allowed to wither. Known as 'Withering', this process softens up the tea leaves. Then it is rolled, exposing essential oils to the air and starting the oxidization process. The 'Rolling' process helps to break down the cell structure of the leaves, emitting several of the oils and juices contained in each cell.



and polymerized, have a wide range of molecular weights, and are less well characterized.

### Green Tea

This tea is not put to the withering or fermentation processes, but rather is steamed directly after harvest. The 'Steaming' process immediately kills the bacteria and enzymes in the leaves preventing fermentation, and also helps to soften the leaves for the rolling process. Similar to black tea, after the 'Rolling' process, green tea must be unrolled; however, after the leaves are unrolled they are 'Fired' to prevent further fermentation. Green teas include 'Lung Ching', 'Bancha' and 'Sencha' and are most popular tea in the east.

The chemical composition of green tea is very similar to that of fresh tea leaves (Balentine, 1992). It contains polyphenols, viz. flavanols, flavandiols, flavonoids, phenolic acids. The

polyphenols are the active players in green tea, mediating both taste profile and biological actions. These compounds may account for up to 30% of the dry weight. Most of the green tea polyphenols are flavan-3-ols, commonly known as catechins (Balentine *et al*, 1997) which are 6-16 % of the dry green tea leaves (Zhu & Chen, 1999). Four main catechin derivatives present in green tea are: (–)-epicatechin (EC), (–)-epigallocatechin (EGC), (–)-epicatechin gallate (ECG) and (–)-epigallocatechin gallate (EGCG).

Besides the catechins, green tea also contains kaempferol, quercetin and myricetin glycosides which are present in very low concentrations (Balentine *et al*, 1997; Graham, 1992). Caffeine, theobromine, and theophylline are the principal alkaloids (about 4% of the dry weight) reported from green tea. In addition, there are phenolic acids such gallic acids and characteristic amino acids such as theanine (Yang, 1999).

leaves used for making oolong are partially 'Withered', then immediately allowed to 'Ferment'. The leaves are then 'Fired', 'Rolled', and then allowed to partially ferment again before they are Fired once again. Examples of oolong teas include 'Black Dragon' and 'Pouchong' (Pao-Chung).

Oolong tea contains monomeric catechins, theaflavins, and thearubigins. Some characteristic components, such as epigallocatechin esters, theasinensins, dimeric catechins, and dimeric proanthocyanidins, are also found in oolong tea.

### White Tea

This rare type of tea is unfermented. White tea is minimally processed. Generally air dried and slightly oxidized only. The highest quality white teas are the tea leaves, picked before the leaf buds have opened and still covered with silky white hairs.

### Green Tea and Nutrition

Green tea contains manganese and potassium, two minerals vital to the human body. Manganese is needed by our body to promote bone growth and several other developments, which take place in our bodies. Among other sources, tea is one of the richest food products containing this mineral. Five to six cups of tea taken daily provide us about 45-50% of our daily requirement of manganese (based on an adult intake of 2000 calories).

Potassium is also essential for human beings for maintaining a normal heartbeat. Potassium also assists nerves and muscles to function. Further, it



Tea plant

### Oolong Tea

Being a medium between black and green tea, it is partially fermented. The





regulates fluid levels or balance inside of each cell. Deficiency of potassium can lead to irregular heartbeat and, generally, body fatigue. Five to six cups of tea taken daily can provide as much as 75% of our daily requirements (based on an adult intake of 2000 calories).

Besides, above two nutrients, green tea provides 70 % of our daily fluoride intake, which is needed to support bone mineralization and protect teeth against dental caries (Rao, 1984; <http://www.tea.co.uk>).

Green tea contains vitamin C in amounts comparable to lemon, vitamin K comparable to green vegetables and  $\beta$ -carotene comparable to spinach and carrots. Green tea is also high in folic acid and the polyphenols further increase its synthesis by the intestinal microflora.

Taken on its own, tea has no calories and negligible amounts of proteins and carbohydrates. However the addition of milk to tea increases its nutritional content.

### Health benefits of Tea

Extensive research over the last 15 years conducted by various research scientists and national organizations, including research work under the aegis of the FAO, seems to prove that apart from being a stimulant and a refreshing beverage, tea is also a health drink (Sharma, 2000).

Eastern cultures have considered green tea as a healthy drink for centuries. Most historical claims of the benefits of drinking tea are, however, anecdotal. Science is now stepping into the ring, and studies are beginning to investigate tea's effects on health by considering data from

epidemiology, clinical studies and laboratory research on animals, as well as mechanistic studies *in vitro*. Some of its medicinal properties reported in scientific literature have been summarised below.

#### Anti-diabetic activity

Since blood sugar tends to increase with age, accelerating aging by crosslinking with proteins (glycation), the ability of tea to lower serum glucose levels is extremely important as part of its anti-aging benefits. A study comparing the effects of 75-day feeding of green tea and black tea to aged rats found that green tea lowered blood sugar slightly better than black tea (23.9% and 22.8%, respectively) (Deng *et al*, 1998). The ability to significantly lower blood glucose has been confirmed also in studies using diabetic rats. Both green and black teas were shown to possess anti-diabetic activity, and to be effective both in the prevention and treatment of diabetes. The main mechanism seems to be the inhibition of the activity of starch digesting enzyme amylase. Tea inhibits both salivary and intestinal amylase, so that starch is broken down more slowly, and the rise in serum glucose is thus minimized. In addition, according to one recent study, tea may reduce the intestinal absorption of glucose (Kreydiyyeh *et al*, 1994). A relatively little known compound found in onions and in tea, especially green tea, called diphenylamine, seems to have a strong sugar-lowering action (Karawya *et al*, 1984).

#### Cardiovascular properties

Cardiovascular heart disease (CVD) is widely prevalent in the western

world, probably as a fall-out of sedentary lifestyle and unhealthy dietary habits. The main forms of CVD are Coronary heart disease (CHD) and Stroke.

#### Coronary Heart Disease (CHD):

While epidemiologic studies do not provide conclusive evidence that increased tea consumption offers protection from coronary heart disease, several well-designed studies have demonstrated significant risk reduction in consumers of green and black tea. A variety of studies showed the preventive effect of green tea consumption against atherosclerosis in human as well as in experimental animals and coronary heart disease (Weisburger *et al*, 1997; Tijburg, 1997; Thelle, 1995). Tea consumption has also been shown to reduce the risk of high blood cholesterol concentrations and high blood pressure (Stensvold, 1992). A study that followed 8,522 Japanese men for a period of 12 years found that men who drank at least 10 cups (~32 ounces) of green tea daily had a lower risk of death from CHD than those who drank 3 cups/day (~10 ounces/day) or less (Nakachi *et al*, 2000).

**Stroke:** A prospective cohort study has demonstrated an inverse relationship between green tea consumption and the incidence of stroke. One study followed 5,910 Japanese women, who neither smoked nor drank alcohol, for 4 years (Sato *et al*, 1989) revealed that the incidence of stroke was significantly lower in women who consumed at least 3-4 cups/day (~10-14 ounces/day) of green tea. Green tea inhibits thrombosis (the leading cause of heart attack and stroke) as effectively as aspirin although via different mechanisms. Green tea has also been shown to elevate the level of HDL



cholesterol (Imai & Nakachi, 1995), which is the good cholesterol.

**Endothelial function (Blood vessel dilation):** The inner lining of blood vessels, known as the endothelium, plays an important role in preventing cardiovascular disease (Ross, 1999). Numerous studies have shown a positive correlation between tea consumption and normal endothelial function (Duffy *et al*, 2001; Hodgson *et al*, 2002).

### Anticancer properties

Cancer is often thought of as a single disease; however in reality it is a term that covers a range of malignant conditions that may affect almost any organ or tissue in the body. Consumption of tea on a regular basis has been associated with reduced risk of several forms of cancer in human populations and mouse models. There is strong evidence linking green tea use to reduction in cancer risk in parts of Asia (Dreosti *et al*, 1997). The flavonoids found in green tea have been found to be powerful antioxidants *in vitro* and have been identified as potential cancer preventive compounds (Middleton *et al*, 1994; Smith & Dou, 2001; Lynn-Cook *et al*, 1999). The suggested mechanisms of action of tea in cancer prevention include:

- Trapping of ultimate carcinogens (Yang & Wang, 1993).
  - Ability to inhibit cell proliferation (Yang & Wang, 1993).
  - Modulation of gut microflora (Yamamoto *et al*, 1997) (associated with colon cancer).
  - Antimicrobial actions (Weisburger, 1999; Diker & Hascelik, 1994) (associated with gastric cancer).
- Lung cancer:** Witshci *et al* (1998) demonstrated a protective effect of green tea extracts against tobacco smoke-induced lung tumors in A/J mice. It has also been noted that those Japanese smokers who consume a lot of green tea seem to enjoy protection against lung cancer (Chung, 1998; Lee, 1997).
- Stomach cancer:** Men who consumed 7 cups or more of green tea a day had a 31% lower risk of stomach cancer. A Japanese *in vitro* study found that both green tea extract and epigallocatechin gallate caused a concentration- and time-dependent growth inhibition and apoptosis (programmed cell death) in a line of human stomach cancer cells (Hibasami *et al*, 1998).
- The beneficial effects of green tea extracts have been reported on animals in adenoma and adenocarcinoma formation in the small intestine (Hirose *et al*, 1993), hepatocarcinogenesis (Qin *et al*, 1997) as well as in the case of mammary gland carcinogenesis (Tanaka *et al*, 1997).
- Antioxidant activity (Xu *et al*, 1992; Wang *et al*, 1989).
  - Ability to inhibit nitrosamine reactions (Wang *et al*, 1992).
  - Modulation of carcinogen-metabolizing enzymes (Jakun *et al*, 1997).

**Leukaemia:** Green tea consumption may prove effective as an adjuvant therapy for the treatment of leukaemia. The particularly bioactive catechin in green tea, epigallocatechin gallate, was found to inhibit the proliferation of human and mouse leukaemic cells *in vitro* (Otsuka *et al*, 1998). Even at the lower concentration, DNA synthesis by leukemic cells was reduced by more than 50%, while normal cells were unharmed. Another study, using the leukemic blast cells from patients with acute myeloblastic leukaemia, a particularly aggressive and often deadly form of leukaemia, found that epigallocatechin gallate inhibited the effect of tumour necrosis and other growth factors (Asano *et al*, 1997; Yang *et al*, 1998). Yet another study revealed that green tea extract is a potent nucleoside transport inhibitor, interfering with tumour cells' repair of DNA after chemotherapy. Thus green tea extract markedly potentiated the effectiveness of chemotherapy.

**Angiogenesis:** Green tea possesses the ability to inhibit angiogenesis – the development of new blood vessels that tumours need in order to grow and metastasize (McCarty, 1998). Green tea treated mice showed significant reduction in tumour growth on the induction of lung cancer and EGCG has been hypothesized to be responsible for angiogenic suppression (Demeule *et al*, 2002).

**Metastasis:** Green tea also prevents metastasis. Cancer cells secrete special enzymes called collagenases in order to penetrate and colonize various tissues. It is the metastatic process that is lethal, not

the primary tumour. A study done at the University of Shizuoka in Japan found that epigallocatechin gallate does in fact inhibit the secretion of collagenases by tumour cells thus arresting their ability to invade normal tissue. Black tea theaflavins were also effective (Sazuka *et al*, 1997).

### **Oral Health**

Dental diseases can result in acute pain, aesthetic problems and can increase the risk of tooth loss. Damage to or loss of teeth may result from dental caries, acid erosion or periodontal disease.

Epidemiological surveys have reported that some populations who drink green or black tea on a regular basis have a reduced number of carious teeth (Ramsey *et al*, 1975; Onisi, 1985; Cao *et al*, 1987). The fluoride in green tea, on incorporation into tooth enamel, could make it harder and more resistant to acid attack. Other components of green tea such as catechins, caffeine and tocopherol have been shown to be effective in increasing the acid resistance of tooth enamel (Yu *et al*, 1995). Green tea catechins have also exhibited inhibitory effects on the growth of cariogenic bacteria by inhibiting the adherence and growth of plaque bacteria at the tooth surface (Otake *et al*, 1991).

### **Weight Loss**

Controlled trials in humans found that consumption of green tea or oolong tea extract resulted in an average increase in 24-hour energy expenditure of 3-4%, apparently due to increased fat oxidation and thermogenesis. Thermogenesis is heat production that is not accounted for by

the resting metabolic rate or physical activity, and is responsible for about 15% of the daily energy expenditure (Brooks *et al*, 1996).

Recent studies on green tea's thermogenic properties have demonstrated a synergistic interaction between caffeine and catechin polyphenols that appears to prolong sympathetic stimulation of thermogenesis (Dulloo *et al*, 2000). A human study of green tea extract containing 90 mg EGCG taken three times daily concluded that men taking the extract burned 266 more calories per day than did those in the placebo group and that green tea extract's thermogenic effects may play a role in controlling obesity. Green tea polyphenols have also been shown to markedly inhibit digestive lipases *in vitro*, resulting in decreased lipolysis of triglycerides, which may translate to reduced fat digestion in humans (Dulloo *et al*, 2000). Further research is required before any firm conclusions about green tea and weight loss can be drawn.

### **Skin Protection**

A number of studies on animals have shown that topical treatment or oral consumption of green tea polyphenols, inhibit chemical carcinogen or ultraviolet radiation-induced skin tumours in different animal models (Wang *et al*, 1992; Conney *et al*, 1999). Treatment of skin with green tea polyphenols has been shown to have a beneficial effect on the biochemical pathways involved in skin inflammation, cell proliferation and chemical tumour promotion. These results have been confirmed in a human model, where topical application of green tea

polyphenols protected against UV light induced DNA damage (Katiyar *et al*, 2000). Based on results mainly from animal studies, many companies are now supplementing their skin care products with green tea extracts. However, the effects on human skin are still not well understood and further research in this field is required.

### **Other Benefits**

#### **Neuroprotective effects**

Kakuda (2002) has studied the neuroprotective effects of theanine and catechins contained in green tea and observed that the death of cultured rat cortical neurons, induced by the application of glutamic acid, was suppressed with exposure to theanine. The neuronal death of the hippocampal CA1 and CA3 regions was also inhibited by the ventricular preadministration of theanine.

#### **Anti-inflammatory effects**

In several studies, the polyphenolic fraction from green tea has been shown to protect against inflammation caused by certain chemicals, such as 12-*O*-tetradecanoylphorbol-13-acetate, a principal irritant in croton oil (Katiyar & Mukhtar, 1996; Katiyar *et al*, 1992, 1993), or by ultraviolet radiation B (290-320 nm) (Agarwal *et al*, 1993). Green tea has also been shown to be effective against the immunosuppression caused by ultraviolet radiation B and shown protection against cytokines induced by tumours (Katiyar *et al*, 1995).



## Kidney function

Decreased kidney function due to aging and kidney failure are a frequent cause of death. Making use of a wide-range of antioxidant protection appears crucial, and flavonoids, including green tea catechins, are very potent antioxidants. Epigallocatechin gallate was shown to induce antioxidant enzymes in the kidneys, as well as to reduce uremic toxins in the blood, suggesting improved kidney function in an animal model of kidney failure. Since green tea has been shown to lower the concentrations of free radicals and lipid peroxides in organs such as the liver and the pancreas, this is likely to be true in the kidneys as well.

Kidney problems are often associated with high blood sugar and consequent glycosylation of various proteins (hence the strong link between kidney failure and diabetes). Since green tea has the ability to lower serum glucose, this is another way in which it helps protect against kidney failure.

Two large prospective studies found green/black tea consumption to be inversely associated with the risk of kidney stones, which decreased by 8% in women (Curhan *et al*, 1998) and 14% in men (Curhan *et al*, 1996) for each 240 ml (8 ounce) cup of tea consumed daily. However, tea consumption has been found to increase urinary oxalate levels in healthy individuals (Massey *et al*, 1993), and some experts continue to advise people with a history of calcium oxalate stones to limit tea consumption (Massey, 2000). Maintaining kidney health is a crucial though often neglected part of anti-aging medicine. Green tea is one of the resources we have for protecting this

critical detoxification system, and it seems to be a particularly powerful one (Greenwell, 1999).

## Antibacterial effects

Green tea catechins also help destroy harmful oral (You, 1993) and intestinal bacteria. When tube-fed patients received 300 mg of tea catechins a day, the putrefactive products in their gastrointestinal tract decreased, and organic acids increased, lowering the pH. The greater acidity is highly beneficial, since it makes the environment inhospitable to harmful bacteria, while beneficial lactic acid bacteria can thrive. Indeed, the bactericidal activity of green tea does not affect lactic acid bacteria. Decreased levels of putrefactive products and improved intestinal flora lead to better digestion, better immune function, and lower risk of colorectal cancer (Hara, 1997).

## Antiviral effects

Recent studies suggest that green tea catechins may inhibit the HIV virus replication, and various other viruses. A study done at the Laboratory of Viral Oncology in Nagoya, Japan, discovered that two catechins found in green tea, epigallocatechin gallate and epicatechin gallate, were able to differentially inhibit the enzymes used by the HIV virus for replication: reverse transcriptase and various DNA and RNA polymerases (Nakane & Ono, 1989). A more recent Chinese study at the Institute of Medical Biotechnology in Beijing found that green tea catechins in general could inhibit the reverse transcriptase or polymerases of

several types of viruses, including HIV-1 and herpes simplex 1 (Tao, 1992). Various polymeric oxidation products of polyphenols have also been found to inhibit the herpes simplex virus. The green tea polyphenol EGCG has been found to block the infectivity of the Influenza virus (Nakayama *et al*, 1993).

## Metal chelation

Flavonoids in general and catechins in particular, chelate metal ions, such as iron and copper. This process might contribute to the antioxidant activity of tea by inhibiting transition metal-catalyzed free radical formation (Rice-Evans, 2000). However, it is not clear whether metal chelation is a physiologically relevant antioxidant activity, since most transition metal ions are bound to proteins *in vivo* where they cannot participate in metal-catalyzed free radical formation. The metal chelating ability of flavonoids likely contributes to the inhibition of non-heme iron absorption by tea.

## Stimulation of detoxification (Phase II) enzyme activity

Phase II detoxifying enzymes promote the excretion of potentially toxic or carcinogenic chemicals. Genes for phase II enzymes contain sequences known as 'antioxidant responsive elements' (AREs). When specific transcription factors bind to AREs, transcription is enhanced. Green tea polyphenols (Yu *et al*, 1997) and individual tea catechins (Chen *et al*, 2000) have been found to increase the transcription of genes containing AREs in



cell culture. Providing white tea, green tea, or green tea polyphenols in the drinking water of animals has been found to significantly increase the activity of phase II enzymes in the liver (Khan *et al*, 1992; Santana-Rios *et al*, 2001).

### **Inhibition of transcription factor activation**

Nuclear factor kappa-B (NF- $\kappa$ B) is a transcription factor, i.e., a complex of proteins that binds to DNA and activates gene transcription. In its inactive form, NF- $\kappa$ B is present in the cytoplasm of cells bound to an inhibitory protein. Phosphorylation of the inhibitory protein results in its degradation, and releases NF- $\kappa$ B to translocate to the nucleus where it binds DNA and activates the transcription of multiple inflammatory and other genes. Genes activated by NF- $\kappa$ B appear to play important roles in the etiology of inflammation, cardiovascular disease and cancer. Green tea catechins and black tea theaflavins have been found to inhibit the phosphorylation of the inhibitory protein and hence, block the activation of NF- $\kappa$ B in cultured cell lines (Pan *et al*, 2001; Nomura *et al*, 2000).

### **Inhibition of cell-signalling pathways**

Tea polyphenols have been found to inhibit proteins known as MAP-kinases whose activity has been implicated in inflammation as well as the transformation of normal cells to cancer cells, cancer cell invasion, the spread of cancer (metastasis), and the development of new blood vessels by tumours (angiogenesis) (Yang *et al*, 2002).

### **Induction of apoptosis**

Unlike normal cells, cancer cells lose the ability to undergo programmed cell death, also known as apoptosis. Tea polyphenols have been found to induce apoptosis in cancer cells in culture (Yang *et al*, 2000), but it is unclear whether they can induce apoptosis in precancerous cells or cancer cells in living organisms.

### **Effects on cell cycle regulation**

Once a cell divides, it passes through a sequence of stages known as the cell cycle before it divides again. Cancer cells divide and grow rapidly. Tea catechins may be able to induce cell cycle arrest and prevent cancer cells from continuing to divide or proliferate in a manner akin to certain tumour suppressor proteins (Yang *et al*, 2000).

### **Interference with receptor binding**

Some cancer cells express receptors for growth factors on their surface membranes. Tea polyphenols may bind to these receptors, preventing growth factors from binding to them, thereby inhibiting their carcinogenic activities (Yang *et al*, 2000).

### **Conclusion**

The benefits of drinking tea in aspects of both mental and physical health have been substantiated by various research organizations. With the advances in modern chemistry, the various components of tea have been analyzed and the health benefits claimed in the past have been attributed to the respective elements.

Extensive research over the last 15 years conducted by various research teams and national organizations, including research work under the aegis of the FAO, seems to prove that apart from being a stimulant and a refreshing beverage, tea is also a health drink.

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## Green Tea in Cosmetics

Green tea is used by the cosmetic industry for a variety of reasons. The activity of green tea as an antioxidant both within the product itself (as a preservative) and on the skin surface helps reduce sun damage to the skin with perceived benefits such as anti-aging and reduce wrinkles. Skin care products with green tea extract are also believed to increase the effectiveness of sunscreens and prevent skin irritation.

Some green tea cosmetic products are: Green Tea Nourishing Eye Gel which works well around eyes, or on whole face for a refreshing, oil-free pick-me-up. Green Tea Eye Cream, helps in the ultimate relief of puffy eyes. Green Tea Day Lotion; Green Tea Day Cream or Basis Face; Green Tea Night Cream; and Green Tea Sunscreen Lotion (<http://www.kovic.com/GreenTea2.html>).