ADVANCED TOPICS IN SCIENCE AND TECHNOLOGY IN CHINA

Liang Chen • Zeno Apostolides
Zong-Mao Chen *Editors*

Global Tea Breeding

Achievements, Challenges and Perspectives

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With 87 figures

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Preface

The tea plant, *Camellia sinensis* (L.) O. Kuntze, originated in the southwestern part of China. Tea is one of the most popular non-alcoholic and healthy beverage in the world. It contributes to massive wealth and job opportunities in many countries, including China, India, Kenya, Sri Lanka, etc. Up to date, tea plants have been cultivated in more than fifty countries in Asia, Africa, South America, Europe and Oceania. According to FAOSTAT (http://faostat.fao.org), the tea harvest acreage was 2,996 kilohectares; the production was 3,885 kilotonnes in 2009. Of this, about 83.8% is produced in Asia, 13.7% in Africa. Tea acreage and production have increased continuously in recent years. The increase is partially a result of the release and wide extension of clonal tea cultivars in the main tea producing countries. So far, more than 500 tea cultivars have been bred and released to the public in China, India, Sri Lanka, Kenya, Japan, Bangladesh Indonesia, and some other countries. Approximately half of the world tea acreage consists of clonal tea gardens.

The tea plant, as a unique crop, from cultivation to harvesting, does not fit into any typical cropping pattern. The production of tea, from processing to marketing, is also specific. The world tea community has lacked a monograph on the subject of tea germplasm and breeding for about 20 years. In recent years, the main tea producing countries have progressed significantly in the field of tea breeding. At the same time, they are facing big challenges owing to the progress of science and technology and the serious demands for tea quality and consistency. This book systematically and comprehensively expounds the achievements, challenges and perspectives of worldwide tea breeding. It consists of several specific topics, such as resistant breeding and molecular assistant selection in about ten different countries. The chapter for each country usually includes (1) a general introduction to the tea industry; (2) the collection, conservation, appraisal and utilization of tea germplasms; (3) conventional and molecular tea breeding and selection techniques; (4) the propagation and extension system for new cultivars; (5) future tendencies, strategies, opportunities and perspectives for world tea breeding which are well discussed. The authors are top tea breeders from China, India, Sri Lanka, Kenya, Japan, Turkey, Indonesia, Korea, Nigeria, etc., accounting for 90% of the world tea production.

We hope that this book will be useful not only to the world tea community to enhance the understanding, exchange and cooperation of tea genetics and breeding in the tea producing countries, to promote the progress of world tea breeding, to help us breed more desirable new tea cultivars to meet the demands of different markets and consumers in the world, but also as a reference for other woody perennial species.

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Abbreviations

AFLP	Amplified fragment length polymorphism
AMOVA	Analysis of molecular variance
amsl	above mean sea level
bp	base pair
C	Catechin
CG	Catechin gallate
CNGTR	China National Germplasm Tea Repository
CTC	Crush, tear and curl
DUS	Distinctness, Uniformity and Stability
EC	Epicatechin
ECG	Epicatechin gallate
EGC	Epigallocatechin
EGCG	Epigallocatechin gallate
EST-SSR	Expressed sequence tag based simple sequence repeat
EST	Expressed sequence tag
FAO	Food and Agriculture Organization of the United Nations
GC	Gallocatechin
GCG	Gallocatechin gallate
GPS	Global Positioning System
gSSR	Genomic SSR
GUS	β-glucuronidase
ISSR	Inter simple sequence repeat
ITC	International Tea Committee
LD	Linkage disequilibrium
MAS	marker-assisted selection
NACTC	National Authentication Committee of Tea Cultivars
NCBI	National Center for Biotechnology Information
N_m	Gene flow
PCR	Polymerase chain reaction
PIC	Polymorphism information content
QTLs	Quantitative traits loci
RAPD	Random amplified polymorphic DNA

RFLP	Restriction fragment length polymorphism
RT	Reverse transcription
RTA	Ratio of tea polyphenols to amino acids
SNP	Single nucleotide polymorphism
SSR	Simple sequence repeat
STS	Sequence tagged site
TF	Theaflavin
TP	Tea polyphenols
TR	Thearubigin
UPASI	The United Planters' Association of Southern India
UPOV	International Union for the Protection of New Varieties of Plants

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Delicious and Healthy Tea: An Overview

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Abstract: The tea plant, *Camellia sinensis* (L.) O. Kuntze, originated in the southwestern part of China, and has been cultivated there for approximately 5,000 years. Now tea plants are cultivated in 52 countries around the world. More than one-half of the population of the world consumes tea. The daily consumption of tea is approximately 3 billion cups all over the world. Tea, coffee and cocoa are the three most popular non-alcoholic beverages in the world.

1.1 Development of the Global Tea Industry

The discovery and drinking of tea originated during the "Shen-Nong" era in ancient China, around 5,000 years ago. Originally, tea was used as a medicine for various illnesses and it can be traced back as early as 2737 B.C. in ancient China (Yamanishi, 1995). Tea production has developed rapidly since the Tang Dynasty (618 – 907 A.D.) and has been accepted as a beverage. However, tea has achieved popularity in other parts of the world only since the middle of the 17th century. Commercial cultivation of tea gradually expanded to Indonesia, India and Sri Lanka until the middle of the 19th century (Chen & Yang, 2011). The history of tea cultivation in Africa is relatively short. The first record of cultivation in Africa was in 1850; however, the tea industry developed until the middle of the 20th century. Now, tea plants are distributed worldwide ranging in latitude from 43° N (Georgia) to 27° S (Argentina). It is now grown commercially in tropical, subtropical and temperate climatic regions of Asia, Africa and South America, and also in limited areas in North America, Australia and Europe. In 2010, the tea growing area in the world amounted to approximately 3,692 kilohectares and the total output amounted 4,162 kilotonnes (ITC, 2011). The average yield in the world now is around 1,110 kg/ha. The following 8 major tea producing countries, namely China, India, Kenya, Sri Lanka, Vietnam, Turkey, Indonesia and Japan, accounted for 88.9% of the world production (Table 1.1). China is the largest tea producing country once again in the world since 2005. The production in 2010 amounted to 1,475.1 kilotonnes and occupied 35.4% of the total world production. The total world export amounted to 1,728.8 kilotonnes in 2010 and was about 41.5% of total production. Kenya exports the most tea in the world, as 95% of production (ITC, 2011). Virtually all tea produced in Japan and about 74% of that produced in China is green tea. About 60% of consumers prefer black tea and the rest consume green tea and Oolong tea. Green tea is preferred in China, Japan and Middle East countries; Oolong tea is mainly consumed in the eastern part of China and in Japan. In terms of annual tea consumption per capita, Kuwait has the highest value at 2.86 kg (triennial average in the period of 2008 – 2010), followed by Ireland (2.31 kg), Qatar (2.04 kg), Turkey (2.02 kg), Afghanistan (2.01 kg) and United Kingdom (1.97 kg) (ITC, 2011).

Table 1.1 Tea production in the major tea producing countries

Country	1940	1950	1960	1970	1980	1990	2000	2010
China	100.0	62.5	136.0	136.0	303.7	540.1	683.3	1,475.1
India	210.4	278.0	321.0	418.5	569.5	720.3	980.8	966.4
Kenya	5.4	6.7	13.7	41.0	89.8	197.0	345.8	399.0
Sri Lanka	120.2	143.4	197.1	212.2	191.3	234.0	318.6	331.4
Vietnam	—	—	4.5	5.5	21.5	32.2	63.7	157.0
Turkey	—	0.2	5.9	33.4	95.8	126.7	155.0	148.0
Indonesia	—	35.3	46.0	44.0	98.6	145.1	137.5	129.2
Japan	58.2	41.7	78.9	91.1	102.3	89.9	93.0	93.0
Subtotal	494.2	567.8	803.1	981.7	1,472.5	2,085.3	2,777.7	3,699.1
World total	1,007.2	1,075.3	1,380.8	1,633.7	2,360.0	2,409.4	2,928.6	4,162.3

1.2 Botanical Characteristics

Although the tea plant is an ancient plant with a long history, the confusion of the nomenclature has continued for almost two centuries. As early as 1753, Linnaeus described the tea plant as *Thea sinensis*, and it was modified to *Camellia sinensis* in August of the same year. Since then, the genus name of *Thea* and *Camellia* has had a checkered history. In the second edition of *Species Plantarum*, Linnaeus abandoned the former name and described the two species separately: *Thea bohea* and *T. viridis*. Watt in India named it *Camellia thea* in 1907; Cohen-Stuart in Indonesia used a new name of *C. theifera*. Sealy in the UK (1958) also gave the same name, *Camellia sinensis* (L.) O. Kuntze and included two varieties: var. *sinensis* (small-leaf variety) and var. *assamica* (large-leaf variety). Since then, despite some papers contributing to the botanical name of the tea plant, *Camellia sinensis* (L.) O. Kuntze, uniformity has been achieved (Chen & Yu, 1994).

Botanically, tea plants belong to the order Theales, family Theaceae, genus *Camellia* L., section *Thea* (L.) Dyer. There are different numbers of species and varieties in the section *Thea* according to different taxonomic systems. Nevertheless, most of the cultivated varieties and cultivars of the tea plant belong to one species, *Camellia sinensis* (L.) O. Kuntze, including var. *sinensis*, var. *assamica* (Masters) Kitamura and var. *pubilimba* Chang. The tea plant is a perennial evergreen; the aerial portion of the tea plant is grown as a tree, semi-tree or shrub depending on the external environment. The var. *sinensis* tea plant usually grows into a shrub about 1 – 5 m high, characterized by more or less virgate stems. Leaves are small, hard and dark-green in color with a dull surface. The var. *assamica* tea plant is described as an erect tree with many branches, 8 – 12 m high. Leaves are 15 – 20 cm long, light-green in color with a glossy surface (Fig. 1.1) (Ming, 2000).

Fig. 1.1. *Camellia sinensis* (L.) O. Kuntze (1 – 3), *C. sinensis* var. *assamica* (Masters) Kitamura (4 – 6). 1: Flower and branch; 2: Gynoecium; 3: Fruit; 4: Flower and branch; 5: Gynoecium; 6: Under surface of leave

The fresh shoots are the economic harvest of the tea plant. The phyllotaxy of leaves on the shoot is alternate. The leaf pose on the stem can be erect, semi-erect, horizontal or drooping, according to the variety. Leaves are leathery in texture, with silvery or light-yellow colored pubescences on the under surface of tender leaves. There are 7 – 15 pairs of veins on the leaf. The lateral veins curve upward and connect with the upper veins, forming a close transporting network, which is characteristic of the leaves of the tea plant. Leaves are serrated at the margin. The first few new leaves at the flushing period of the tea shoot usually have a characteristic small size, being thick and brittle with a blunt apex; the petiole is wider and flat and called a fish-leaf, or in Indian terminology the *Janam*. Its position on the shoot is of the very greatest importance when considering the standards of plucking. The tea manufactured from the fish-leaf is of low quality. Sometimes the leaf primodium differentiates from the vegetative bud of the tea plant, ceasing growth prematurely instead of developing into a normal leaf. It is termed the dormant bud, or in Indian terminology the *Banjhi*. Normal tea shoots show the distinct periodicity of growth, i.e., after the development of several normal leaves, the *Banjhi* bud forms, thus completing a full periodic shoot growth rhythm.

Tea flowers are bisexual with a slight fragrance and are usually white in color. Their diameter is 2.0 – 5.0 cm. The morphology of the flower is one of the important indexes in the classification of the tea plant. The fruit of the tea plant is green in color, usually three-celled, thick-walled and shinny at first, but then duller and slightly rough later. Tea seed is brown in color, thin-shelled, about 1 – 2 cm in diameter, and round, semi-round in shape.

1.3 Genetics and Breeding

The tea plant is self-incompatible. Long-term allogamy makes it highly heterogeneous and consequently with broad genetic variation. The tea plant is usually diploid, with $2n = 30$ chromosomes. Natural triploid, tetraploid and aneuploid tea cultivars are also found. The genome size is estimated to be about 4.0 Giga bp. The transcriptome of the tea plant is partially sequenced using EST (expressed sequence tags) strategy and high-throughput DNA sequencing technology (Chen *et al*., 2009; Shi *et al*., 2011). The whole genome sequencing of the tea plant is still ongoing in China. It will benefit greatly the genetics and breeding of this crop.

Tea breeding was first started in ancient China. In the late 18th century, vegetative propagation methods using cutting and layering were developed in China. They accelerated the selection and breeding of new tea cultivars. Individual selection from landrace *jats* and natural populations and controlled hybridization are the main breeding methods for the tea plant to date. Recently, mutation breeding and molecular assisted selection (MAS) has been developed with the rapid development of new technologies. The main tea producing countries, such as

China, India, Sri Lanka, Kenya, Japan, etc., have bred and released hundreds of tea cultivars for the tea industry (Table 1.2). The made tea quality and yield increased significantly with the increase in the ratio of clonal tea acreage in the main tea producing countries.

Table 1.2 The national released tea cultivars and ratio of clonal tea gardens of some countries

Country	Year of the first release	National released cultivars	Ratio of clonal tea acreage (%)
China	1985	123 (17 *jats*)+158 local cultivars	46 (2010)
Japan	1953	54	92.1 (2004)
India	—	62+20 (Biclonal seed stocks)	60 (N.E. India, 2011)
Sri Lanka	1958	64	55 (2004)
Kenya	1964	50+11 (Biclonal seed stocks)	60 (2011)

1.4 Physiology and Biochemistry

The tea plant can be grown over a considerable range of conditions from temperate climates to hot, humid subtropics and tropics. However, the optimum mean daily ambient temperature for tea growth ranges between 20 °C and 30 °C. When the mean ambient temperature is higher than 30 °C, the growth of the tea plant is retarded. The tolerance of the tea plant to the minimum temperature varies with the varieties and cultivars, it generally ranges between –3 °C and –15 °C. Tea plants require not only certain amounts of rainfall, 1,000 – 1,700 mm annually, but also rainfall that is well-distributed during the whole year. Although the total rainfall in a year may be adequate for the production of green leaves in most of the tea producing areas in the world, the distribution of the rainfall in growing season may be inadequate in some areas. This can be regulated by irrigation. The optimum pH of soil for tea growing ranges between 4.5 and 6.5 (Chen & Yang, 2011; Zhen *et al*., 2002).

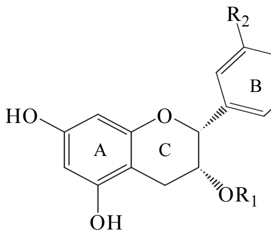
The tea output per unit area is proportional to the coverage in the tea garden. For the purpose of obtaining the maximum productivity, a density of more than 12,000 – 20,000 bushes per ha in large-leaf cultivars and 45,000 – 60,000 bushes in small to median-leaf cultivars is recommended (Chen & Yang, 2011). The economic life of the tea plant is generally around 40 – 50 years. It is recommended to replant new clones when tea plants reach this age. However, such techniques as collar-pruning and heavy-pruning of old bushes are adopted.

The principle of fertilization is to compensate the nutrients removed by the crop and eluted by the rainfall. Generally, the level of nitrogen application is controlled at around 240 – 300 kg per ha and half amounts of potassium are added. The level of phosphorus is fixed at amounts of 60 – 90 kg P_2O_5 per ha and applied every 2 years. The need for microelements by the tea plant is few. It is not important in most of the tea producing countries; however, deficiencies were found in some particular instances. For example, a part of the soil in Sri Lanka and East African countries is zinc deficient; a part of the tea growing area in India, East Africa and Zaire is magnesium deficient. So, the application of microelement fertilizer showed significant effects in some instances (Chen & Yang, 2011; Zhen *et al*., 2002).

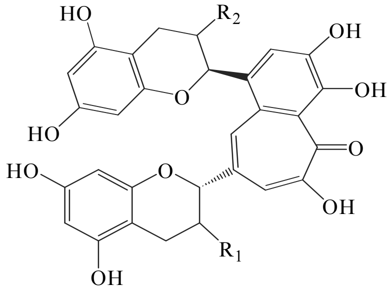
Pruning is a "necessary evil" for the tea plant. The objects of pruning are to maintain the plant permanently in the younger phase, to stimulate the growth of shoots, and to build a rational height of the frame. In mature tea gardens, light-pruning and heavy-pruning should be done alternately. The best time for pruning is during a dormant period, because this is the time when the carbohydrates reserved within the tea plant are at a higher level.

The tea plant is a C_3 plant with high photorespiration. The utilization ratio of solar radiation energy is far lower than that of other C_4 plants. It was estimated that only 7% of photosynthetic products are used in the growth of the tea shoots, 9% in the formation of frame branches, and 84% is exhausted during respiration and other metabolic actions (Chen & Yang, 2011; Zhen *et al*., 2002).

Fresh tea leaves and processed tea consist of a great number of substances which can be roughly divided into two categories: non-volatile compounds and volatile aroma compounds. The non-volatile that constitutes the major part of the tea solids include polyphenols, flavonols, amino acids, carbohydrates, organic acids, caffeine and purine derivatives, vitamins and many others. The physiological effects of caffeine are well known and documented. The most important and characteristic components in tea are the polyphenols and theanine. The total content of tea polyphenols expressed as a percentage of dry weight leaf is around 20% – 30%. They are the key compounds that determine the taste and color of infusion and have proved to have beneficial effects on human health. The most important compounds in tea polyphenols are the catechins. The content of catechins in tea is around 12% – 24% and represents more than 50% of the total amount of tea polyphenols. Six kinds of catechin compounds were isolated from tea. They are the various derivatives of catechins and gallic acids, including catechin (C), epicatechin (EC), gallocatechin (GC), epicatechin gallate (ECG), epigallocatechin (EGC), epigallocatechin gallate (EGCG). Generally, the content of the latter three catechins are relatively higher. The structures of main catechins and theaflavins are listed in Fig. 1.2. The catechin compounds condensed to theaflavin (TF) and thearubigin (TR) during the manufacturing process of black tea. The formation of these compounds makes the infusion orange-red in color. Theanine is an exclusive amino acid for the tea plant (Fig. 1.3); it accounts for about 60% – 70% of total amino acids in tea leaves. The site of theanine biosynthesis is the root and from there it is transferred to younger leaves. The pharmacological and physiological effects of theanine brought about a relaxing effect, the improvement of memory and also showed anticarcinogenic activity.



Epicatechin: $R_1 = R_2 = H$
Epigallocatechin: $R_1 = H$; $R_2 = OH$
Epicatechin-3-gallate: R_1 = Galloyl; $R_2 = H$
Epigallocatechin-3-gallate: R_1 = Galloyl; $R_2 = OH$



Theaflavin: $R_1 = R_2 = OH$
Theaflavin-3-gallate: R_1 = Galloyl; $R_2 = OH$
Theaflavin-3'-gallate: $R_1 = OH$; R_2 = Galloyl
Theaflavin-3,3'-digallate: $R_1 = R_2$ = Galloyl

Fig. 1.2. The structures of catechins and theaflavins

$$C_2H_5\text{—NH—CO—}(CH_2)_2\text{—}\underset{\displaystyle NH_2}{\underset{|}{CH}}\text{—COOH}$$

Fig. 1.3. The structure of theanine

The volatile aroma compounds play an important role in determining the quality of tea. Some of these compounds exist in the fresh leaves; however, most of them are formed during processing. Up to now, more than 600 flavor compounds have been identified in tea, although they exist only in a small amount (0.03% – 0.05% in fresh leaves on a dry basis, 0.005% – 0.01% in green tea and 0.01% – 0.03% in black tea).

With regard to the chemical basis of tea tasting and tea color, it is based on the taste threshold value of chemical components in tea and the reaction of sensory organs to these components. The compounds which play the major role in taste are tea polyphenols, amino acids and polysaccharides. The freshness of green tea is a reflection of the amino acids and the fullness of green tea is a reflection of the suitable ratio of tea polyphenols and amino acids. The catechins and theaflavins are the most important compounds determining the taste of black tea. Strong black tea depends on the content of water extracts and the briskness and fullness of black tea mainly depend on the ratio of caffeine, theaflavins and amino acids. The conjugation of these compounds and caffeine creates the astringency feeling and strong taste. The color of tea and tea infusion are based on certain chemical compounds. The color of green tea is mainly determined by the chlorophyll and some flavone compounds, such as vitexin and isovetexin. Chlorophyll-a is a deep green in color and chlorophyll-b is yellow green in color. The different ratio of chlorophyll-a and chlorophyll-b results in a different grade of green color in green tea. The color of black tea is black in made tea and orange-red in an infusion. These colors are formed by the theaflavin and thearubigin. Theaflavin is yellow in color and thearubigin is red in color. Different ratios of these two compounds constitute the different degree of color. Semi-fermented Oolong tea is generally a green-brown color in made tea and a yellowish red color in an infusion.

1.5 Kinds of Tea and Manufacture

The fresh tea leaves plucked from the tea plant are manufactured into various kinds of tea including green tea, Oolong tea, black tea, etc., by means of different manufacturing methods. In terms of unfermented tea (green tea), the first step in manufacture is to treat the fresh leaves at high temperature and this is called de-enzyming or fixation. The nature of this step is to deactivate the polyphenol oxidase localized within the cells of leaves, so as to stop the fermentation process and maintain the original green color. On the other hand, when the fresh leaves begin withering and are not treated at high temperature, the tea polyphenols are oxidized by the polyphenol oxidase enzyme, thus producing fermented tea (black tea). When the enzymes in the tea leaves are not completely deactivated and the tea polyphenols are not fully oxidized, this produces intermediate tea products between black tea and green tea, termed semi-fermented tea (Oolong tea).

Black tea is the major kind of tea consumed in the world. Congou black tea is manufactured by the most traditional processes including withering, rolling, fermentation and drying. For the convenience of brewing, the tea cutter was developed first in India and the rolling process was changed to a rolling and wringing process; thus, the broken black tea product was produced. Subsequently, some alternative manufacturing machines and methods were developed successively in India, East African countries and China; they include the Rotovane process, CTC (crush, tear and curl) process, LTP (Laurie tea processor) process. The production of CTC black tea has increased rapidly in the past half century and occupied 61.7% of the total black tea production in the world in 2009.

The basic manufacturing processes of green tea include de-enzyming, rolling and drying. The de-enzyming process comprises pan de-enzyming and steam de-enzyming. Steamed green tea is the major tea product produced and consumed in Japan, while roasted green tea is the major green tea product in China.

The basic manufacturing processes of Oolong tea include sunlight withering, light rolling, de-enzyming, rolling and drying. The plucking standard for Oolong tea is different from other kinds of tea. It is recommended that shoots with one bud and three to four leaves be plucked as the raw material when the *Banjhi* is formed on the terminal of a shoot.

Besides the above mentioned three kinds of tea, there are many kinds of tea produced in the world, including dark tea (a kind of post-fermented tea), yellow tea and white tea, scented tea, fruit-flavored tea and instant tea, etc.

1.6 Tea and Human Health

Tea was adopted for medicinal use in ancient China and sustained over a long period of time in Chinese history. Tea was transferred from medicinal use to use as a beverage from the Tang Dynasty. Investigation into the medicinal function of tea developed intensely after the discovery of the inhibitory activity of tea polyphenols on cancer cells firstly reported by Fujiki in Japan (Yoshizawa *et al*., 1987). Up to now, many miraculous medicinal functions have been proved using the investigations conducted throughout the world (Zhen *et al*., 2002; Chen, 2009). The following major functions of tea were verified and described.

1.6.1 Antisenile Activity

Antisenile activity is based on the antioxidative activity and the free radical scavenging effect of tea components. Many investigations showed that tea polyphenols possessed a potent antioxidative activity. Among the individual catechin in green tea, the activity of scavenging the free radicals decreased as follows: EGCG >ECG >EGC>EC.

1.6.2 Improvement in Immunity

The active components in tea may contribute to potential immuno-modulating effects including the innate immune system and the acquired immune system. This is expressed in the increase in leucocyte and lymphocyte amounts and improves the role of interleutin in spleen cells.

1.6.3 Anticaries

The tea plant is a fluorine-accumulating plant. The caries-preventive effect of tea was first believed to be due to its fluoride content. Tea contains high fluoride, which may strengthen tooth enamel and improve dental health. Further investigations indicated tea polyphenol not only could kill the caries bacteria, it also inhibits the activity of glycan transferase, meaning the caries bacteria cannot adhere to the surface of teeth.

1.6.4 Reduction in Blood-Cholesterol and Prevention of Cardiovascular Disorders

Tea drinking could increase the antioxidative activity of blood and improve the blood parameters. Earlier cohort studies in the USA, Norway, India, Saudi Arabia, Japan and the Netherlands suggested an inverse relationship between tea consumption and the risk of death due to heart attack and stroke. Many epidemiological studies showed an inverse association between tea consumption and the risk of cardiovascular diseases. However, conflicting results also existed in human trials. The cardioprotective effects of tea may also be due to its hypolipidemic and hypocholesterolemic activities. Numerous studies with animals have shown that tea consumption can reduce serum and liver lipids and total serum cholesterol. The effect of tea polyphenols on obesity has been verified by many investigations.

1.6.5 Anticarcinogenic Activity

The inhibitory activity of tea extracts on the human cancer cell was firstly reported by Fujiki in 1987 in Japan (Yoshizawa *et al*., 1987). Since then, around several thousand papers on the anticarcinogenic activity of tea have been published in the world. A number of epidemiological studies have shown that there exists an inverse correlation between tea consumption and the incidence of certain kinds of cancer in humans. The popular press heralds tea as a cancer preventive beverage because such an activity has been demonstrated in many animal models. These models include cancers of the skin, lung, oral cavity, esophagus, stomach, liver, small intestine, colon, pancreas, bladder, prostate and mammary glands. Many ecological, case-control and cohort studies have been conducted to investigate the effects of tea consumption on human cancer incidence. However, the results have been inconclusive. For example, studies in northern Italy have suggested a protective effect of tea against oral, pharyngeal and laryngeal cancer. In a case-control study in Shanghai, China, frequent consumption of green tea has been shown to be associated with a lower incidence of esophageal cancer, especially among non-smokers and non-alcohol drinkers. A protective effect against gastric cancer by drinking tea has also been suggested from studies in Kyushu (Japan), northern Turkey and central Sweden, but has not been seen in many other studies from different geographic areas. In studies in Saitama, Japan, women consuming more than 10 cups of tea daily have been shown to have a lower risk of cancer (all sites combined) and increased tea consumption was associated with a lower risk of breast cancer metastasis and recurrence. However, there were also some epidemiological studies showing no significant lower incidence of cancers after tea consumption. It appears that most reports showing positive cancer preventive effects were from studies on Asians who drink predominantly green tea, whereas studies of the black-tea drinking population infrequently observed protective effects. It is possible that the different results connecting tea and cancer are due to the different etiological factors involved as well as the types and quantities of tea consumed in different populations. Investigations conducted over a period of twenty years proved the mechanism of the anticarcinogenic activity of tea components. Many mechanisms have been proposed concerning the inhibitory action of tea against carcinogenesis including the following: antioxidative activity, modulation of the activity of the key enzyme related to carcinogenesis, the anti-proliferative effect, inhibition of cell transformation, inhibition of the