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The health benefits of tea varieties from *Camellia sinensis*

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Abstract

Background and aims: Varieties of tea from the plant *Camellia sinensis* have been consumed for around 50 centuries and today are a popular beverage worldwide. Over the past 30 years much research has gone into the medicinal properties and health benefits that these teas provide consumers. This review aims to consolidate the benefits of tea's antioxidant and antimicrobial properties and evaluate the research to this date.

Methods: This review plans to use the primary literature available from journals and online sources found using search engines. Most recent literature will be used primarily, as well as that from 10-20 years ago for history, and studies using cohorts.

Conclusions: Catechins from non-fermented varieties have both antimicrobial and antioxidant activities which offer protection from cancers, cardiovascular diseases and dental caries. Varieties of fermented teas, namely black tea, where catechins have been converted into thearubigins and theaflavins, have antimicrobial and antioxidant potential but to less of an extent. It is apparent however, that less research using black tea has been done relative to that of green.

Keywords: Catechins, Theaflavins, Thearubigins, Polyphenols, antioxidant, antimicrobial.

Introduction

Tea is consumed around the world, and is the second most consumed drink after water (Ruxton, 2008). Originating from the plant *Camellia sinensis* a range of different types can be produced through various different processing methods. In the UK, black tea is the most popular and statistics from the International Tea committee in 2006/2007 showed that 95% of tea consumed in the UK was black tea (Ruxton, 2008). The remaining 5% consists of Green, White, Oolong and other specialities. Teas are widely known for their health benefits, however scientific research and investigation into the contents of tea has only been undertaken in the past 30 years, despite the beverage being consumed for around the past 50 centuries (Khan and Mukhtar, 2007). Discussions in the literature associate tea with lowering the risk of cancer, lowering the risk of coronary heart disease, improvement of oral health (Ruxton, 2008) antimicrobial health benefits and antioxidant properties (Cabrere et al, 2006). There are also suggestions that tea extracts offer protection against bone loss (Ruxton, 2008), body weight control, anti-hypertensive properties, solar ultraviolet protection, neuroprotective properties and anti-fibrotic properties (Cabrere et al, 2006). Tea therefore provides a very interesting beverage with potential for a variety of medicinal uses and health promoting benefits.

History of tea

The earliest mention of tea on record is from 350 BC in a Chinese word book, with the earliest use as a beverage traced to be by the Chinese as early as 2700 BC (Weisburger, 1997). It was discovered by the herbalist Shen Nong, whilst searching for an antidote to poisonous herbs he discovered medicinal properties from extracts of *Camellia sinensis* (Nie et al. 2008).

Tea drinking culture spread to Japan in the 6th century but was only available to those considered part of privileged society until around 700 years ago. Its appearance in England was due to cultivation of tea in India where British colonies enabled its transport back. Tea in the western world grew in demand due in part to the British popularising it so, and in the mid 1600's it gained value as trade currency for a short while (Weisburger, 1997).

Although proper scientific research was not undertaken into the health benefits of tea until around 30 years ago, reports from 1923 of an army surgeon suggesting tea should be available in soldier's water bottles to help prevent typhoid (Hamilton-Miller, 1995) shows the ancient Chinese beliefs in *Camellia sinensis's* medicinal properties were not lost in transport across to the west and it's uses were slowly becoming more realised, leading to knowledge and research being undertaken today.

Production methods

The *Camellia sinensis* plant matures after 7 years growing best at temperatures between 15 and 25°C, high relative humidity's of 80-90% and relatively high annual rainfall of around 1500-2000mm (Fung et al, 1999).

Black tea is produced from the bud and the first and second leaves of *Camellia sinensis*. These are left to wither so that the moisture content of the leaves are reduced and the cell membranes break, causing enzymes and Polyphenols to be released (Bhattacharyya et al, 2007). These leaves are then cut and rolled which breaks cell compartmentalisation further, and allows Polyphenols to come into contact with polyphenol oxidase enzymes (Rusak et al, 2008). The leaves then enter the fermentation stage of processing. It is the oxidisation of the leaves during this

process which forms their brown coppery colour and produces the tea's aroma. Oxidation with the aid of enzymes is important in black tea as it reduces flavanoids to more complex compounds; thearubigins and theaflavins. The last step of black tea production involves drying with a blast of hot air. This step not only reduces the leaves remaining moisture content but it deactivates the enzymes (Bhattacharyya et al, 2007).

Green tea is produced in a similar way to black tea, but does have some vital differences during production which have important effects on the outcome. With green tea, the leaves are only subjected to partial withering and then steamed. This initial steam heating process destroys the polyphenol oxidase enzymes so that the Polyphenols remain as flavanoids and simple catechins, not the more complex compounds found as a result of fermentation such as in black tea (Cabrere et al, 2006). The leaves are then rolled, cut, dried and then finally fired without fermentation. The lack of fermentation and polyphenol oxidase enzymes is also why the leaves retain their green colour (Cabrere et al, 2006). Polyphenols are substances which contain two or more phenol units. They are organic compounds which occur naturally and are currently regarded as the most abundant antioxidants in the diet (Hannig et al, 2009). Polyphenols are most commonly present in plants in the form of flavanoids which occur as catechins or theaflavins. The former primarily found in green tea, and the later primarily found in black tea (Trautwein et al, 2009).

Oolong tea is produced in the same way as black tea, but has a shorter fermentation period. Because of this, oolong tea has less time to oxidise and so the final tea product has an appearance and taste somewhere between that of green tea and black tea (Rusak et al, 2008).

White tea is also steamed and then dried to prevent any fermentation in a similar way to green tea. White tea is steamed and then dried immediately after picking with no withering, making it the least processed tea of the group (Rusak et al, 2008). This method of processing, and the fact that white tea is prepared from very young leaves or buds which are still covered with tiny silvery hairs, only at the start of spring once each year, means that white tea has a quite light and delicate flavour (Rusak et al, 2008).

Health benefits

The health benefitting properties of tea's are predominantly due to the presence of polyphenols, compounds credited for the antimicrobial and antioxidant abilities observed in tea. Polyphenols are present in all varieties of teas from *Camellia sinensis*; however, due to the process of fermentation in black tea and partially in oolong tea, the types of polyphenols present are different. Green tea polyphenols consist primarily of catechins which are simple flavanoids as they have not been oxidised by fermentation. There are four main catechins found in green tea; epigallocatechin-3-gallate (EGCG), epigallocatechin (EGC), epicatechin-3-gallate (ECG) and epicatechin (EC). EGCG is the most abundant catechin making up for about 59% of the total (Cabrera et al, 2006). These simple flavanoids are converted into more complex compounds with a higher molecular weight when they become oxidised during the enzymatic action occurring during fermentation. These compounds are theaflavins and thearubigins which are predominately found in black tea and partially in oolong tea (Cabrera et al, 2006).

Antimicrobial properties

The anti microbial effects of extracts from *Camellia sinensis* has been observed in several studies looking at multiple species of bacteria. *Staphylococcus aureus*, and *Staphylococcus epidermidis*, were inhibited and killed by tea extracts, as were *Salmonella typhi*, *Salmonella typhimurium*, and *Salmonella enteritidis* (Hamilton-Miller, 1995). A similar study also showed whilst using tea extracts at the concentration of an average beverage, that methicillin resistant *Staphylococcus aureus* was inhibited (Hamilton-Miler, 1995). Green tea extracts are found to be the most effective antimicrobial agent in comparison to other tea's from *Camellia sinensis* such as black and oolong due to the presence of catechins in green tea. Reports suggest that catechins have a greater antimicrobial effect on gram-positive bacteria than they do on gram-negative bacteria (Kim et al, 2008).

In 2008 a study by Kim et al looked at the antimicrobial and antifungal properties of green tea extracts against the vaginal pathogens; *Proteus mirabilis*, *Streptococcus pyogenes* and *Candida albicans*. Their results showed that green tea extracts, noticeably catechin EGCG, was effective at inhibiting the bacteria. This data suggests that the fermentation process during black tea production has a negative impact on the antimicrobial properties by converting the simple catechins into the more complex theaflavins and thearubigins which have lower and possibly absent antimicrobial properties. At the same time Kim et al looked at the impacts of pH and temperature on the effectiveness of green tea extract and catechins. Their observations regarding temperature changes found that antimicrobial activity was unaffected by high temperatures. Extracts were heated for 30 minutes at 80, 100 and 121 °C and at each range a high proportion of the catechins remained stable. This is obviously useful information in respect to tea when as a beverage it is subjected to high temperatures during preparation. The results using different pH ranges found that the green tea extracts had the greatest antimicrobial properties between pH 4 and pH 10, and it was observed that antimicrobial activity increased with higher pH (Kim et al, 2008).

Studies using herbal teas produced from plants other than *Camellia sinensis*, such as a study undertaken in 2010 using tea extracts from the plants; *Lippia javanica*, *Lippia scaberrima*, *Lippia rehmannii* and *Lippia wilmsii* show that these teas also have antimicrobial properties against human pathogens including *Staphylococcus aureus* (Shikanga et al, 2010). This species of plant contains phenol compounds of which the antimicrobial properties are attributed to in *Camellia sinensis* tea extracts.

There is however some disagreement in the literature regarding the extents of the antimicrobial properties of teas. This is predominantly a result of the variations in the experiments carried out where there are differing strains of bacteria used, as well as differences in the strength of the tea used, and the location the tea was sourced from having an effect on the mineral contents of the tea's (Hamilton-Miller, 1995).

Antioxidant properties

Tea, in particular green tea, is considered to be a good source of antioxidants due to the larger proportion of EGCG that it contains. Because EGCG is an effective antioxidant and is not present in black teas as a result of fermentation, green tea is known to have a higher antioxidant capacity than black tea and studies have shown that green tea extracts in fact have a higher antioxidant activity than other known

natural antioxidants such as Brussels sprouts, garlic and spinach (Cabrera, 2006). Within the body during normal metabolic processes and respiration, reactive oxygen species (ROS) are created and damage macromolecules such as DNA and lipids when the body's antioxidant defence systems become overwhelmed. A small amount of damage however will still take place over time and is thought to be one of the main causes of aging (Maurya and Rizvi 2009). For this reason it is very beneficial and indeed necessary to consume compounds with antioxidant activity to reduce the effects of ROS. Polyphenols in tea are able to trap ROS due to their vicinal dihydroxy or trihydroxy structure which prevents damage to macromolecules by chelating metal ions. This structure is also able to quench free radicals by allowing electron delocalisation (Khan and Mukhtar, 2007).

Evidence of the protective effect of Tea catechins can be seen from a study in 2009 by Maurya and Rizvi where the effect of tea catechins were tested on the presence of erythrocyte malondialdehyde; a natural marker for oxidative stress. Their results showed a reduced level of malondialdehyde when there was a presence of tea catechins and they reported that 'tea catechins show significant protection to erythrocyte against oxidative stress' (Maurya and Rizvi 2009).

Anticarcinogenic properties

It is accepted that green tea contains cancer preventing properties and there have been many observations of a correlation between tumour cell inhibition and tumour cell apoptosis with the application of green tea. Studies also show that these tea extracts are able to reduce cancer cells without having detrimental effect on normal tissue cells. Tea extracts have been shown in various studies to contain cancer preventing properties due to the antioxidant activities of polyphenols. Again it is the EGCG catechin present in green tea extracts that is the most effective anticancer compound in tea's, giving green tea the most effective anticancer properties (Cabrera, 2006). For this reason it has been suggested that black tea has considerably less anticancer potential relative to that of green tea. However, there has been less research undertaken on the anticancer properties of theaflavins and thearubigins in black tea compared to the work undertaken using green tea (Goldbohm et al, 1996).

Goldbohm et al (1996) conducted research into the cancer preventing potentials of black tea. This was done by collecting data on subjects in a cohort in the Netherlands using a questionnaire into dietary habits and then following up cases of breast, lung, colorectal, and stomach cancer. The results observed were not completely conclusive however, and there was no clear correlation between the intake of black tea and a reduced incidence of cancer. There was in fact a positive correlation between the risk of breast cancer and black tea consumption, where black tea drinkers had a slightly higher incidence rate of breast cancer than those who did not drink tea. This however did not increase along with black tea consumption rates. These results could be down to the conduct of the experiment, such as differences in diet to what was expressed in the questionnaire or changes in diet over time after the questionnaire was completed. It could also be a result of the tea quantity and strength, or that the tea's constituents were not made available to the right area of the body at sufficient times to prevent cancers. Another explanation could simply be that the theaflavins and thearubigins in black tea are not sufficiently able to protect against cancer so the results are purely random (Goldbohm et al, 1996).

Animal models to test the anticancer effectiveness of EGCG extracts from green tea have shown them to be able to prevent cancer in the lungs, stomach, oesophagus, duodenum, pancreas, liver, breasts and colon (Ahmad and Mukhtar, 1999). A population based study was conducted in China by Setiawan et al, to look at the protective effects of green tea against stomach cancer and chronic gastritis. After adjustments for potential confounders the results clearly show a reduced risk of stomach cancer and gastritis for those who consumed green tea. Those who drank green tea had a 48% reduced risk of stomach cancer, and a 51% lower risk of gastritis, and in both cases the risk of contracting the disease was reduced with increase in tea drinking duration (Setiawan et al, 2001).

Oral hygiene

Observations that those who regularly consume a relatively large quantity of tea on a regular basis have a decreased incidence of tooth decay (Kubo et al, 1992) can be supported by evidence that tea extracts have antimicrobial properties. In particular, studies have found that tea extracts show a bactericidal action towards the primary bacterium to cause dental caries; *Streptococcus mutans* (Muroi and Kubo, 1993). It is also apparent that tea extracts are able to reduce the risk of cancer in the mouth cavity. Both effects are due to the presence of theaflavins and catechins in tea, and studies using animal tests and human trials have shown a reduction in tooth decay, plaques and cavities as a result of using tea extracts (Lee et al, 2004). For example a study was undertaken looking at polyphenolic beverages including red wine, citrus tea, black tea, green tea, and grape juice, and found that each of these beverages reduced the amount of bacteria present on tooth enamel to the extent that they could potentially reduce bio film in the oral cavity enough to reduce the risk of disease. It was found that of these beverages, black tea was one of the three most effective at reducing the bio film (Hannig et al, 2009). Experiments into the usefulness of black tea and green tea at delivering polyphenols with cancer preventing potential showed that tea leaves did have the ability to act as a slow release source of catechins and theaflavins when held in the mouth for a time period of around 5 minutes, and so do have a use as an oral cancer preventative as well as a dental caries preventive (Lee et al, 2004).

Cardiovascular disease

Cardiovascular disease has become more prominent in recent decades as societies become more developed and lifestyles become more sedentary, diets higher in fat and longer life expectancies increasing the occurrence of non-communicable diseases (Yusuf et al, 2001). It is possible that tea may have a preventative effect on cardiovascular disease because of the flavanoids that tea extracts contain. Research suggests that flavanoids inhibit platelet aggregation which is quite a major contributing factor in coronary diseases (Vita, 2005). The antioxidant activity of tea is thought to play a large part in preventing cardiovascular problems as a contributing factor to cardiovascular disease are ROS damaging the endothelial lining and causing atherosclerosis. Therefore the antioxidant properties of tea flavanoids should be able to reduce this effect (Song et al, 2006). There are disagreements in the literature as to the extent to which tea is able to reduce the risk of cardiovascular disease. There are studies which suggest that the incidence of cardiovascular disease is reduced in tea drinkers, as is the risk of mortality from strokes (Trevisanato and Kim, 2000), yet a study beginning in 1986 following subjects for a course of 10 years found no link between flavanoid uptake and stroke mortality, but

data did suggest that flavanoid uptake could reduce the risk of Coronary heart disease (Yochum et al, 1998). However, a study of 17228 subjects was conducted in the US to observe tea drinking habits and associations with coronary heart disease, and no correlation between the two were found (Sesso et al, 2003).

Effect of caffeine

Average caffeine concentration in a cup of home brewed tea is around 27mg per cup (Gilbert et al, 1976) but levels can vary widely due to differing preparations (Quinlan et al, 1999). Caffeine is found in tea leaves and is an important feature of tea as a beverage due to its stimulating effect (Fernandez et al, 2000). Research undertaken by Quinlan et al (1999) concluded that caffeine had a significant effect on energetic arousal, stimulated autonomic nervous system to increase alertness, and produce improvements in mood. There are several theories and possible mechanisms suggesting how caffeine affects the body and brain to cause these symptoms but the most substantially supported mode is adenosine receptor antagonism. It is also suggested that caffeine increases the turnover of several neuro-transmitters (Fredholm et al, 1999). Caffeine also aids the health benefitting properties in tea and studies show that caffeine treatment was able to reduce the incidence of lung cancer, although it is not as effective as EGCG it was shown to have a significant inhibitory effect (Khan and Mukhtar, 2007). In contrast to this however, there are negative effects on health believed to result from caffeine consumption, be this consumption relatively high there are links between caffeine and irritability, nervousness and insomnia. Very high levels of caffeine can cause nausea and diarrhoea, and there have even been links to coronary artery disease (Jacobson and Kulling, 1989).

Conclusions

It is clear that the components in tea responsible for major health benefits are also the same components which differ as a result of oxidation during preparation. It would appear that green tea and other varieties where fermentation is not part of production processes and so contain catechins rather than thearubigins and theaflavins have greater health benefitting potential. Green tea stands above black tea as having greater antioxidant potential, and research by Goldbohm et al (1996) found no correlation between black tea consumption and protection from cardiovascular disease, whereas studies using catechins showed there was a reduction in disease cases (Ahmad and Mukhtar, 1999, Setiawan et al, 2001). A similar pattern can be seen for antimicrobial properties, where green tea catechins were found to be more effective (Kim et al, 2008). However, black tea was found to have a fair antimicrobial potential in studies regarding oral bacteria (Lee et al, 2004).

It is clear from the literature that teas from *Camellia sinensis* do have beneficial medicinal properties, relevant to the needs of modern populations.

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