Phenolic Compunds in Green Tea and Green Tea Kombucha

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### Introduction

Green tea, white tea, and black tea each originate from the *Camellia sinensis* plant which is native to the tropical and temperate regions of Asia, Africa, and South America (Gopal et al. 2016). Small leaves and leaf buds are unfermented and used to make green tea, while white tea is composed of semi-fermented buds, and black tea is composed of fully fermented old leaves (NCSU 2022). Tea is a globally consumed beverage second only to water and the drink is praised for its numerous health benefits. Briefly, tea has anti-carcinogenic, anti-angiogenic, anti-mutagenic, anti-inflammatory, anti-bacterial, hypocholesterolemic, anti-diabetic, and shows protection against Parkinson’s and Alzheimer’s disease (Chacko et al. 2010, Gopal et al. 2016). These and many other health benefits are mainly attributed to green tea polyphenols, less so to flavonols and gallic acid derivatives, vitamins, minerals, enzymes, and others (Gopal et al. 2016). Another health drink rising in popularity is Kombucha - which is a fermented beverage resulting from a symbiotic culture of bacteria and yeast (SCOBY) in a sweetened tea solution for about two weeks. The flavor profile shifts from sweet to tart to sour with increased fermentation time, temperature and SCOBY microbe composition. The total phenolic content of kombucha made from green or black tea is over three times greater than regular green or black tea (Zhou et al. 2022). Green tea and kombuchas are popular for their numerous health benefits and fermentation with a SCOBY enhances these benefits and is suggested by Jakubczyk et al. (2020) a diet including kombucha can help support the body’s antioxidative response, especially for those exposed to mental and physical stress.

### Polyphenols of Green Tea and Green Tea Kombucha

The components of free tea that gives the drink its health benefits comes from polyphenols, flavanols, and gallic acid derivatives (Gopal et al. 2016). Important compounds among the polyphenols includes alkaloids, carbohydrates, catechins, enzymes, free amino acids, minerals and vitamins. The health benefits are most particularly associated with the catechins which comprise 25% - 35% of green tea dry weight. The two most effective antioxidant compounds are EGCG and ECG. EGCG is also the most active and abundant - one cup of green tea could have 100-200 mg EGCG. Gopal et al. (2016) found that EGCG can help prevent dental cavities, inhibition of multiple drug resistant Staphylococcus aureus, and inhibition of HIV infection. The antioxidant potential of green tea can be increased 3.25x (Zhou et al. 2022) through fermentation with a SCOBY - symbiotic culture of bacteria and yeast. Fermentation is the metabolic breakdown of carbohydrates producing chemical changes in the organic substances via the action of enzymes associated with the SCOBY (Redzepi and Zilber 2018).

GTK antioxidant activity increased 3.25x (Zhou et al. 2022) Chemical profile (Jakubczyk et al. 2020)

### Health Benefits of Green Tea

Green tea (GT) has antioxidative, anti-carcinogenic, anti-diabetic, anti-hypertensive, anti-inflammatory, anti-mutagenic, anti-proliferative, anti-thrombogenic, among many other properties (Velayutham et al. 2008, Chacko et al. 2010, Gopal et al. 2016) giving the drink its status as a health drink. Heinrich et al. (2011) have shown that a flavanoid-rich diet can help prevent certain cancers and cardiovascular diseases, specifically related to UV-induced damage following sun exposure in women. Polyphenols in GT were shown to protect against many damaging effects of UV radiation, such as sunburn response, immunosuppression, and photo-aging. Flavonoids - epigallocatechingallate (EGCG), epicatechingallate (ECG), and epicatechin (EC) - are easily absorbable and bioavailable upon ingestion with the latter two primarily absorbed in the small intestine and 20-50% recovered in urine. They show that consumption of GT with ~1400 mg of catechins per serving can reduce UV-induced erythema by 16% at 6 weeks and 25% at 12 weeks. Prolonged consumption of GT polyphenols and carotenoids at 6 months decreases overall solar damage and at 12 months reduces UV-induced erythema telangiectasis. This research shows that the body readily absorbs polyphenolic compounds and is able to use and recycle them to some extant before excretion.

Green tea extract (GTE), a concentrated form of GT mainly consisting of antioxidants, shows effects on working memory modulation by increasing neural connectivity (Schmidt et al. 2014). EGCG increases connectivity from the right superior parietal lobule to the middle frontal gyrus and connectivity is positively correlated with task performance. Protection of cognitive function by EGCG is accomplished through antioxidation, iron-chelation, and modulation of cell signalling and cell survival pathways. These actions were shown to reduce oxidative stress induced by neurotoxicity, promote neural plasticity in mice, decrease beta-amyloid levels and plaques in Alzheimer’s mice, and facilitate Calcium-dependent glutamate release in rats. Mice and rats are biologically analogous to humans and the effects shown can be translated to humans. These effects shown in GTE by Schmidt et al. (2014) indicate possible effects on neurodegenerative diseases such as Alzheimer’s and Parkinson’s in humans.

Obesity is a global problem and a catechin-rich diet has been shown to decrease intra-abdominal fat (IAF) in an overweight population (Wang et al. 2010). They show that regular consumption of catechin-rich GT for greater than 90 days led to significant responses in body weight, waist circumference, and the most consistent effect in IAF. Catechin-rich diets have been shown to increase lipolysis during moderate-intensity exercise and decrease IAF [Venables et al. (2008); Wang.2010]. GTE was shown to inhibit catechol 0-methyltransferase(5,6) and increase fat oxidation by 17% through lipolysis. Venables et al. (2008) show that GTE effects are not limited to fat oxidation. In men, GTE consumption can increase insulin sensitivity by 13% and improve glycemic control, thus reducing the risk of type II diabetes.

Several studies have found a positive correlation between GT consumption and cardiovascular health. In a review by Velayutham et al. (2008), they found evidence that GT catechins improve blood lipid profiles, regulate vascular tone, prevent vascular inflammation, inhibit vascular smooth muscle proliferation, and inhibit thrombogenesis. In this review they found that plasma catechin levels were 0.2-2%, indicating that bioavailability of catechins is lower than amount absorbed. Despite this limitation in GT, the authors confirm the health benefits in literature with emphasis on cardiovascular health. They show that catechins positively affect plasma lipid profile and vascular function and inhibitory effects on oxidation, vascular inflammation, atherogenesis, and thrombogenesis. GT catechins antioxidant activity scavenges free radicals, chelates transition-metal ions, inhibit pro-oxidant enzymes in favor of antioxidant enzymes.

### Health benefits of Green Tea Kombucha

### Kombucha limitations

Fermentation time (Hsieh et al. 2021) Catechin degradation (Jayabalan et al. 2007)

### Future research

GT v GTK v PGT v PGTK

As noted by Heinrich et al. (2011), GT catechins have a range of effects similar to that of cocoa polyphenols, an addition of cocoa to kombucha during the secondary fermentation could cause a synergistic effect with GT polyphenols.

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