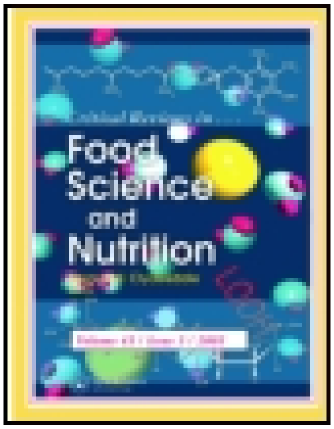

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A Minireview of Effects of Green Tea on Energy Expenditure

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A Minireview of Effects of Green Tea on Energy Expenditure

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In recent years, individuals have begun to tend more frequently to some natural and herbal products to be used alone or as a combination with diet and exercise for ensuring the weight loss. Green tea is the leading one of these products. In some studies, it is reported that the green tea causes an increase in thermogenesis and substrate with fat oxidation by affecting on the sympathetic nervous system. It is reported that green tea has two main components that are associated with energy expenditure. One of them is caffeine and the other is catechin content.

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Each of these two components has an impact on energy mechanism separately. In this minireview article, mechanisms of action and effects of caffeine and catechin, which are found in green tea composition, on energy expenditure are assessed.

Keywords Green tea, thermogenesis, energy expenditure, caffeine, catechin

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INTRODUCTION

According to the 2013 World Tea Market Report tea is the most consumed beverage in the world (Anon, 2013). Besides being the most consumed and tasty beverage, it is reported with the conducted in vivo, in vitro, animal and human studies that tea has important potential health effects on some chronic diseases such as cardiovascular and cerebravascular diseases, diabetes, some cancer types and obesity (Lin et al., 2003; Vuong, 2014). Although the potential health benefits of the green tea has been known especially in the Asian community for centuries, the interest in green tea has increased in the Western communities and in Turkey in the recent years. One of the most important reasons of this increasing interest is that the obesity is reported as becoming a globally epidemiologic case and it is increasingly posing a health threat day by day (Turk et al., 2009).

In recent years, individuals have begun to tend more frequently to some natural and herbal products to be used alone or as a combination with diet and exercise for ensuring the weight loss. Either as a beverage or in capsule form, green tea is one of the leading ones of those products. In some studies conducted it is reported that the green tea affects on the sympathetic nervous system and causes increase in the thermogenesis and substrate together with fat oxidation. At the same time, it is reported that it has potential effects of body weight control by causing inhibition of some enzymes which work in appetite mechanism, lipid metabolism and nutritional element absorption (Rains, et al., 2011). The effects of green tea on energy metabolism and body weight are related with the bioactive components in the components of the green tea.

This minireview article examines the effects of caffeine and catechin, which are included in the chemical components and components of green tea, on the energy expenditure.

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1. Green Tea and Its Chemical Component

Today, different kinds of tea are produced by applying various processes to tea plant or *Camellia sinensis (L.) O Kuntze* in its Latin name. The most familiar of them are black and green teas. Black tea is produced after the oxidation of fresh and young tea plant petals together with its bud in appropriate methods during decolourization, bending, and fermentation processes. And the green tea is produced by transforming all the enzymes to an inactive form by applying a short time heat shock on the tea petals and buds without applying decolourization and fermentation processes (Ahmed, 2013).

When the chemical compound of the green tea, which is a kind of non oxidized tea, is examined, 35% of its dry weight includes polyphenols such as; flavonols and falavone-3-ols. 60-80% of them are falavone-3-ols, also known as catechins. Green tea includes almost two times the catechins that black tea includes. 50-80% of the total amount of the catechin in green tea is composed of Epigallocatechin-3-gallat (EGCG) and it is the most dominant catechin form of green tea (Khan and Mukhtar, 2007). The other catechins of green tea are epicatechin (ECG, 13.6%), Epigallocatechin (EGC, 19%), epicatechin (EC, 6.4%) and catechin. In addition, green tea also includes some polyphenols like caffeine, theanine, theaflavin, thearubigin, quarcetin, cholorogenic acid and gallic acid (Rains, et al., 2011).

Brewed green tea (250 ml) includes 50-100 mg catechin in average. A lot of different factors like the tea plant used, brewing period, temperature of the water used for brewing affect the composition of the bioactive components in the green tea. For that reason, the amount of the bioactive components in the green tea varies (Lin et al., 2003). Average values of some flavanoids in green tea are given in Table 1 below.

As in coffee, cacao, coke and in some food, there is caffein naturally in tea as well. The caffein content of the tea varies according to some variables such as the brewing period, tea and water rate, the size of the cup in which it is served and green tea (250 mg) includes 30-50 ml caffein in average (Diepvens et al., 2007).

2. The Effect of Green Tea on Energy Expenditure

There are two main components of green tea reported as related with energy expenditure. One of them is caffeine and the other is catechin content. Both components have separate effects on energy mechanism.

2.1 Caffeine

2.1.1. Thermal Effect Mechanism of Caffeine

Caffeine (1,3,7 trimethylxantine) component, which is the purine alkaloid of green tea, has an thermal effect. It causes its thermal effect over various metabolic mechanisms. The most familiar one of those mechanisms is the inhibition of phosphodiesterase enzyme (Diepvens et al., 2007; Dulloo et al.,1992). Phosphodiesterase enzyme is regressed with intra cellular cyclic amino mono phosphate, and hydrolyses cyclic AMP to AMP. However, cyclic AMP concentration increases again after caffeine consumption and central nervous system activity increases because protein kinase A is activated (Diepvens et al., 2007). At the same time inactive hormone sensitive lipase level increases and lipolysis is stimulated (Acheson et al.,2004). Besides, caffeine, in addition to phosphodiesterase inhibition, effects on thermogenesis through the stimulation of substrates in Cori cycle and free fat acid triglyceride cycle (Diepvens et al., 2007; Dulloo et al.,1992; Acheson et al.,2004).

Caffeine's being a ryanodine receptor antagonist and stimulating glycolysis and ATP turnover by causing calcium ion canals in skeletal muscle sarcoplasmatic reticulum are some of the noradrenergic thermal effect mechanisms of caffeine (Dulloo et al.,1992).

Besides, caffeine may cause increase in the gene expressions of the various unpaired proteins that affect thermogenesis as well. It makes that through enabling phosphodiesterase inhibition and protein kinase A activatin by cyclic APM. Increases in thermogenesis may occur in that way (Diepvens et al., 2007; Acheson et al.,2004).

2.1.2. Effect of Caffeine on Energy Expenditure

When the studies on assessing the effects of caffeine on energy are examined, it is generally reported that thermal effect of caffeine continues between 30 or 150 minutes after caffeine consumption (Collins et al., 1994). It is also reported that the half life of caffeine is 5 hours and its thermal effect decreases at the 3rd hour and almost returns back to the starting level before consuming caffeine (Compher et al., 2006).

Level and duration of thermal effect of caffeine may change according to the dose. In a study it was found out that 79 kcal energy expenditure was calculated in the adult individuals who consume an average of 300 mg caffeine daily (Tarnopolsky, 1994). In another study it was found out that upto 3.4-7.6% increase may occur in energy spending in 24 hours in the healthy thin individuals by <500 mg/day caffeine consumption (Rudelle et al., 2007). Following 200-350 mg caffeine consuming in healthy male individuals an increase of 7-11% in the first 30 minutes, 9-16% in the 3rd hour of basal metabolic rate (BMR) was observed (Collins et al., 1994). In a randomized single blind study conducted on 20 healthy young women volunteers they were made to consume 150 ml de-caffeine coffee or coffee 200 mg caffeine in it. At the end of the study an average of 7±4% (0.30±0.20 kj/minute) increase occurred in thermogenesis for duration of 3 hours on the individuals who drank coffee with caffeine (Koot and Deurenberg P, 1995). In another double blind study with placebo control 20 healthy male individual at normal height were given tablets with 500 mg caffeine. When the acute thermal respond was measured during 4 hours following the consumption, it was observed that a similar 6% (72725 kj in 4 hours) thermal respond increase occurred (Belza et al., 2009).

Thermal effect of caffeine may change according to the age and body composition. In the studies where the effects according to the age were evaluated, it was reported that caffeine causes less increase in the thermal respond in older individuals than the younger ones. In a placebo controlled double blind study conducted to support that hypothesis 10 young (21-31 years old) and 10 old (50-67 years old) healthy women were given placebo or caffeine (5 mg/kg fatless body mass). As a result, thermal energy expenditure after caffeine intake increased 15.4% (1.09±0.14-1.24±0.13 kcal/minute) in the young women and 7.8% (0.98±0.14-1.06±0.12 kcal/minute) in the old women. Similarly, respond in the thermogenesis in the young women was sharper and more continuous than the older women (15.5±7 kcal/90 minutes; 6.9±5 kcal/90 minutes) (Arciero et al., 2000).

The results of the study conducted to search the effect of body weight and composition on the thermal energy expenditure according to caffeine was irrelevant. In a study, 10 thin and 10 obese women individuals were given coffee with caffeine in a session and coffee without caffeine in another session. As a result, it was reported that thermogenesis was observed lower in obese women than the thin ones (respectively; 4.9%±2.0; 7.6% ±1.3), thermal respond continued all night long at the thin women and thermal effect disappeared both at thin and obese women the next day (Bracco et al., 1995). In another study, where the effect of caffeine on the thermal respond in thin individuals was examined, 136 obese and thin individuals, who were paired according to their ages, were loaded caffeine (4 mg/kg ideal body weight), and their basal metabolism rates (BMR) and thermal responds were measured 30 minutes after loading. As a result there was no difference observed between two groups in terms of BMR and thermal respond; however, it was found out that thermal effect and BMR varied in obese individuals according to their body compositions (Yoshida et al., 1995). Again in the same study, 30 obese individuals were later taken into low calorie diet and exercise programme for 2 months and their body weights together with their body fat rates decreased significantly. Thermal respond of caffeine changed according to their body weight loss (r: 06943) (Yoshida et al., 1995).

As a result, although depending on some variables, the conducted studies show that caffeine relatively increases the thermal respond. However, the potential changes on body weight on the long term depending on caffeine caused by thermal respond varieties are still one of the most discussed topics. European Food Safety Authority (EFSA) has examined the effects of caffeine intake on acute energy expenditure and its relation with body weight with 11 studies in order to clarify this issue. In the end, it is reported that various doses of caffeine is effective on the acute energy expenditure; however, there is not enough scientific data to suggest clearly its effect on the body weight and body composition (EFSA, 2011).

2.2. Catechins

2.2.1. Thermal Effect Mechanisms of Catechins

Central nervous system activity regularizes the resting energy expenditure, which is the most important component of daily energy expenditure. It affects norepinephrine ion canals and substrate cycle and increases ATP usage. The catechins in the green tea inhibits catechol-O-methyl transferase enzyme (COMT), which exits almost in all the tissues, and consequently degradation of cathecolic components like neropinephrin (Shixian et al., 2006). Because the COMT becomes inhibited, norepinephrine in cannot be degraded. As a result, sympathetic nervous system continuously goes under stimulation with the existence of norepinephrine and connects to β-adeno-receptors and causes an increase in the energy expenditure and fat oxidation (Westerterp-Plantenga et al.,2006).

That effect of catechins on energy metabolism is not the same for every ethnic group. For example; it is reported that Asian individuals are 3 times more sensitive than the Caucasian individuals to the change in thermogenesis depending on catechin (Hodgson et al., 2006; Palmatier et al., 1999). Hodgson et al, who searched for its reason, reported that there were great differences between those two populations in flavonoid-O-methylation, which is the major pathway of flavonoid metabolism and where COMT enzyme plays a role (Hodgson et al., 2006). In another study, it was found out that enzyme activity was higher in Asian individuals and there was Val/Val polymorphism in COMTL allele. In Caucasian population on the other hand, the resistance against the change in thermogenesis depended on the lower enzyme activity and the existence of Met/Met polymorphism in COMTL allele (Palmatier et al., 1999). That study results

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partly explains the reasons of differences in some intervention studies, in which green tea and caffeine mixtures were given.

The nutrition differences may change the effect of catechins on the energy metabolisms as well. For example; protein intakes based on milk and milk products are higher among Caucasians. This may cause the occurrence of protein-polyphenol complex and decreases especially in the gastric hydrolysis in the digestion system. That also occurs as another mechanism (Hursel ve Westerterp-Plantenga, 2009a).

All of those mechanisms bring light in different thermal responds not only for Asians and Caucasians, but also in the other races.

2.2.2. Effect of Green Tea Catechins on Energy Expenditure

In addition to caffeine in the tea, one of the effect mechanisms of the catechins on the body weight is its effect on increasing energy expenditure. It was reported in many studies that the caffeine in the green tea stimulates the thermogenesis in humans and makes fat oxidation (Berube-Parent et al., 2005; Dulloo et al., 1999). However, the fact that the green tea stimulates more thermogenesis than its caffeine content brings in mind the existence of other biologic active substances in its content and that increased the interest in catechins (Dulloo et al., 1999).

In 1999, Dulloo et al. showed for the first time that the catechins increased the oxidation of brown fat tissue and that stimulated the thermogenesis (Dulloo et al., 1999). Again in another study, individual were made to consume green tea extract [EGCG + caffeine (90/50 mg)], caffeine (50 mg) or placebo capsules daily in 3 different sessions. As a result (4%=328 kj) increase in 24 hour energy expenditure and an important amount of increase in fat oxidation happened in the group that was given green tea extract compared to placebo or only caffeine intervention. That study brought light in to the fact that green tea had thermal effect because of the other bioactive components in addition to its caffeine content (Borchardt et al., 1975).

On the other hand, the results of the studies examining the effects of different doses of the green tea catechins on the energy expenditure are inconsistent. In a study conducted by Gregersen et al, the effects of green tea catechins in different doses (493-840 mg + 150 mg caffeine) on energy expenditure for 13.5 hours in young males were compared. The results showed that a non-essential (2%) increase in energy expenditure between different doses occurred and the most important difference occurred in the highest EGCG dose (600 mg) and only in the 150 mg caffeine application (Gregersen et al., 2008). However, in another study where the change in effect in thermogenesis based on ECGC dose, the male individuals were given 3 different doses of 90, 200, 300 or 400 mg ECGC and 200 mg caffeine mixture. In the results, it was found out that when compared to placebo without caffeine, EGCG and caffeine caused 8% increase in energy expenditure in 24 hours nad every dose of EGCG caused the same effect in energy expenditure (Berube-Parent et al., 2005). There is a need for more studies for the clarification of this issue.

The number of the studies, which examines the effects of green tea catechins free from caffeine on thermogenesis, are very limited. In a study, 6 obese individuals were given 300 EGCG for two days; however, in the end it was found out that there was no change in the pre-prandial and postprandial energy expenditure (Boschmann and Thielecke, 2009). Actually, in a lot of studies it is reported that, compared to when only EGCG was given, the amount of energy expenditure in 24 hours increased more and caffeine and catechins caused synergistic effect on thermogenesis when the green tea catechins were given combined with caffeine. For that reason, in a lot of studies the effect of the combination of both on the energy expenditure was focused more and that hypothesis was supported in various studies (Dulloo et al., 1999; Westerterp-Plantenga, 2010, Zeng et al., 2004).

In a similar study conducted by Ruelle et al, 31 thin young males and 31 thin young females were given 3 portions of 94 mg EGCG and 100 mg caffeine containing thermal drink (3 x 250 ml) for 3 days. Following the consumption of thermal drink an important increase (4.6%=445.2 kj) in the energy expenditure in 24 hours occurred (Rudelle et al., 2007). In addition, Komatsu et al found out that energy expenditure increased 4% (%49.5 kj) approximately 2 hours after the consumption of oolong tea containing 161 mg caffeine and 156 mg EGCG (Komatsu et al., 2003).

One of the most important limitations of the studies examining the effect of green tea catechins and caffeine components on the thermogenesis is ruling out the varieties in the possible sensitivity of the individuals who regularly consume caffeine and/ or catechin. In a study that supports this hypothesis, individuals with 76 kg of weight and obese ones, who regularly consume high or low levels of caffeine, were given 270 mg EGCG + 150 mg caffeine mixture. As a result, thermogenesis and DMH changes in the individuals, who regularly consume high amounts of caffeine (>300 mg/day), was lower compared to the individuals, who consume lower amounts of caffeine (<300 mg/day) (Westerterp-Planteng et al., 2005). So, this fact is important while discussing the effects of green tea catechin and caffeine on thermogenesis.

How would the effect of green tea catechins on thermogenesis affect the body weight and composition is another equivocal topic. In a number of studies, it is reported that when the green tea catechins are consumed in doses of 270-1200 mg/day, it would affect on the body weights and compositions of obese individuals (Whang et al., 2010; Auvichayapat et al., 2008). It is not yet clear for how long consuming of the dose would have effect on body weight. However, this topic was examined in a meta-analysis study where the effects of green tea catechins on the body weight assessed and it was reported that body weight loss would occur at the end of 12 weeks (Hursel et al., 2009b).

CONCLUSIONS AND RECOMMENDATIONS

Both the catechins and the caffeine, which are the major components of green tea, inhibit the enzymes taking role in the pathways, where the norepinephrine is active and affect thermogenesis. Because the central nervous system activity is affected from the norepinephrine concentration, the more norepinephrine activity means the more activity and energy expenditure. However, more than catechins alone, both the catechins and caffeine together effect on the thermogenesis as a synergist and that effect may change in different races according to the age, dose and body weight. For that reason this issue should be examined with different caffeine and catechin doses on various races, ages and BMI groups.

Most of the studies examining the effect of green tea on energy expenditure have focused on the acute effects of caffeine and catechin. The studies examining the effects of the green tea thermal effects on the body weight in the long term are limited in the literature. Clarification that topic is important in order to prove the anti-obesity effect of green tea depending on thermogenesis.

In addition, another important topic is that the capsule forms of green tea were used in general in the studies focusing on that subject. When it is considered that the natural and capsule forms are in different matrixes and bio efficacy, using the green tea in its natural form in the green tea studies would bring more light on that subject.

REFERENCES

Acheson, K.J., Gremaud, G., Meirim, I., Montigon, F., Krebs, Y., Fay, L.B., Gay, L.J., Schneiter, P., Schindler, C., Tappy, L. (2004). Metabolic effects of caffeine in humans: lipid oxidation or futile cycling? *Am J Clin Nutr* **79**(1): 40-6.

Ahmed, S., Stepp J.R. (2013). Green Tea: The Plants, Processing, Manufacturing and Production. In: Tea in Health and Disease Prevention, 1st Edition, pp.19-31. Preedy, V., Ed., Academic Press.

Anon. (2013). World Tea News Market Reports. Increasing Value for the World's Most Consumed Beverage. Issue: 4.

Arciero, P.J., Bougopoulos, C.L., Nindl, B.C., Benowitz, N.L. (2000). Influence of age on the thermic response to caffeine in women. *Metabolism* **49**(1): 101-7.

Auvichayapat, P., Prapochanung, M., Tunkamnerdthai, O., Sripanidkulchai, B.O., Auvichayapat. N., Thinkhamrop, B., Kunhasura, S., Wongpratoom, S., Sinawat, S., Hongprapas, P. (2008). Effectiveness of green tea on weight reduction in obese Thais: A randomized, controlled trial. *Physiol Behav* **93**(3): 486-91.

Belza, A., Toubro, S., Astrup, A. (2009). The effect of caffeine, green tea and tyrosine on thermogenesis and energy intake. *Eur J Clin Nutr* **63**(1): 57-64.

Berube-Parent, S., Pelletier, C., Dore, J., Tremblay, A. (2005). Effects of encapsulated green tea and Guarana extracts containing a mixture of epigallocatechin-3-gallate and caffeine on 24 h energy expenditure and fat oxidation in men. *Br J Nutr*, **94**(3): 432-6.

Borchardt, R.T, Huber, J.A. (1975). Catechol O-methyltransferase, Structure–activity relationships for inhibition by flavonoids. *J Med Chem* **18**: 120–2.

Boschmann, M., Thielecke, F. (2007). The effects of epigallocatechin-3-gallate on thermogenesis and fat oxidation in obese men: a pilot study. J Am Coll Nutr **26**(4): 389-395.

Bracco, D., Ferrarra, J.M., Arnaud, M.J., Jéquier, E., Schutz, Y. (1995). Effects of caffeine on energy metabolism, heart rate, and methylxanthine metabolism in lean and obese women. *Am J Physiol* **269**(4 Pt 1): 671-8.

Collins, L., Cornelius, M., Voegel, L.R., Walker, J.F., Stamford, B.A. (1994). Effect of caffeine and/or cigarette smoking on resting energy expenditure. *Int J Obes Relat Metab Disord* **18**(8): 551-6.

Compher C, Frankenfield D, Keim N, Roth-Yousey L. (2006). Best Practice Methods to Apply to Measurement of Resting Metabolic Rate in Adults: A Systematic Review. *J Am Diet Assoc* **106**: 881-903

Diepvens, K., Westerterp, K.R., Westerterp-Plantenga, M.S. (2007). Obesity and thermogenesis related to the consumption of caffeine, ephedrine, capsaicin, and green tea. *Am J Physiol Regul Integr Comp Physiol* **292**(1): 77-85.

Dulloo, A., Seydoux, J., Girardier, L. (1992). Potentiation of the thermogenic antiobesity effects of ephedrine by dietary methylxanthines: adenosine antagonism or phosphodiesterase inhibition? *Metabolism* **41**(11): 1233-41.

Dulloo, A.G., Duret, C., Rohrer, D., Girardier, L., Mensi, N., Fathi, M., Chantre, P., Vandermander, J. (1999). Efficacy of a green tea extract rich in catechin polyphenols and caffeine in increasing 24-h energy expenditure and fat oxidation in humans. *Am J Clin Nutr* **70**(6): 1040-5.

European Food Safety Authority (EFSA). (2011). Scientific Opinion on the substantiation of health claims related to caffeine and increased fat oxidation leading to a reduction in body fat mass, increased energy expenditure leading to a reduction in body weight, increased alertness and increased attention pursuant to Article 13(1) of Regulation (EC) No 1924/20061. *EFSA Journal* **9**(4): 2054.

Gregersen, N.T., Bitz, C., Krog-Mikkelsen, I., Hels, O., Kovacs, E.M., Rycroft, J.A., Frandsen, E., Mela, D.J., Astrup, A. (2009). Effect of moderate intakes of different tea catechins and caffeine on acute measures of energy metabolism under sedentary conditions. *Br J Nutr* **102**(8): 1187-94.

Hodgson, J.M.,Puddey, I.B., Burke, V., Croft, K.D. (2006). Is reversal of endothelial dysfunction by tea related to flavonoid metabolism? *Br J Nutr* **95**(1): 14-7.

Hursel, R., Viechtbauer, W., Westerterp-Plantenga, M. (2009b). The effects of green tea on weight loss and weight maintenance: a meta-analysis. *Int J Obes (Lond)* **33**(9): 956-61.

Hursel, R., Westerterp-Plantenga, M.S. (2009a). Green tea catechin plus caffeine supplementation to a high-protein diet has no additional effect on body weight maintenance after weight loss. *Am J Clin Nutr* **89**(3): 822-30.

Khan, N., Mukhtar, H. (2007). Tea polyphenols for health promotion. *Life Sci* **81**(7): 519-33.

Komatsu, T., Nakamori, M., Komatsu, K., Hosoda, K., Okamura, M., Toyama, K., Ishikura, Y., Sakai, T., Kunii, D., Yamamoto, S. (2003). Oolong tea increases energy metabolism in Japanese females. *J Med Invest* **50**(3-4): 170-5.

Koot, P., Deurenberg, P. (1995). Comparison of changes in energy expenditure and body temperatures after caffeine consumption. *Ann Nutr Metab* **39**(3): 135-42.

 ACCEPTED MANUSCRIPT

Lin, Y.S., Tsai, Y.J., Tsay, J.S., Lin, J.K. (2003). Factors affecting the levels of tea polyphenols and caffeine in tea leaves. *J Agric Food Chem* **51**(7): 1864-73.

Palmatier, M.A., Kang, A.M., Kidd, K.K. (1999). Global variation in the frequencies of functionally different catechol-O-methyltransferase alleles. *Biol Psychiatry* **46**(4): 557-67.

Rains, T.M., Agarwal, S., Maki, K.C. (2011). Antiobesity effects of green tea catechins: a mechanistic review. *J Nutr Biochem* **22**(1): 1-7.

Rudelle, S., Ferruzzi, M.G., Cristiani, I., Moulin, J., Macé, K., Acheson, K.J., Tappy, L. (2007). Effect of a Thermogenic Beverage on 24-Hour Energy Metabolism in Humans. *Obesity (Silver Spring)* **15**(2): 349-55.

Shixian, Q., VanCrey, B., Shi, J., Kakuda, Y., Jiang, Y. (2006). Green tea extract thermogenesis-induced weight loss by epigallocatechin gallate inhibition of catechol-O-methyltransferase. *J Med Food* **9**(4): 451-8.

Tarnopolsky, M.A. (1994). Caffeine and endurance performance. *Sports Med* **18**(2): 109-25.

Turk, M.W., Yang, K., Hravnak, M., Sereika SM, Ewing, L.J., Burke, L.E. (2009). Randomized clinical trials of weight-loss maintenance: A review. *J Cardiovasc Nurs* **24**(1): 58-80.

Vuong, Q.V. (2014). Epidemiological Evidence Linking Tea Consumption to Human Health: A Review. *Crit Rev Food Sci Nutr* **54**(4): 523-536.

Wang, H., Wen, Y., Du, Y., Yan, X., Guo, H., Rycroft, J.A., Boon, N., Kovacs, E.M., Mela, D.J. (2010). Effects of catechin enriched green tea on body composition. *Obesity (Silver Spring, Md)* **18**(4): 773-9.

Westerterp-Plantenga, M. (2010). Green tea catechins, caffeine and body-weight regulation. *Physiol Behav* **100**(1): 42-6.

Westerterp-Plantenga, M., Diepvens, K., Joosen, A.M., Bérubé-Parent, S., Tremblay, A. (2006). Metabolic effects of spices, teas, and caffeine. Physiol Behav **89**(1): 85-91.

Westerterp-Plantenga, M.S., Lejeune, M.P., Kovacs, E.M. (2005). Body weight loss and weight maintenance in relation to habitual caffeine intake and green tea supplementation. *Obes Res* **13**(7): 1195-204.

Yoshida, T., Sakane, N., Umekawa, T., Kondo, M. (1994). Relationship between basal metabolic rate, thermogenic response to caffeine, and body weight loss following combined low calorie and exercise treatment in obese women. *Int J Obes Relat Metab Disord* **18**(5): 345-5.

Zheng, G., Sayama, K., Okubo, T., Juneja, L.R., Oguni, I. (2004). Anti-obesity effects of three major components of green tea, catechins, caffeine and theanine, in mice. *In Vivo* **18**(1): 55-62.

Table 1 Flavanoid Composition of Green Tea (Rains et al., 2011).

Component	Amount in 100 ml (mg/100 g)
Epigallocatechin 3-gallat	77.8±7.0
Epicatechin 3 gallat	19.7±2.8
Epigallocatechin	16.7±1.4
Epicatechin	8.9±0.5
Quarcetin	2.7±0.3
Catechin	2.6±1.5
Gallocatechin	1.5±0.0
Thearubigin	1.1±1.1
Theaphlavin	0.1±0.0
Total flavonoids	130.5