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An intervention study on the effect of matcha tea, in drink and snack bar formats, on mood and cognitive performance

Christina Dietz[a], Matthijs Dekker[a], Betina Piqueras-Fiszman[b,*]

[a] Food Quality and Design Group, Wageningen University, The Netherlands
[b] Marketing and Consumer Behaviour Group, Wageningen University, The Netherlands

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ABSTRACT

Matcha tea is gaining popularity throughout the world in recent years and is frequently referred to as a mood-and-brain food. Previous research has demonstrated that three constituents present in matcha tea, L-theanine, epigallocatechin gallate (EGCG), and caffeine, affect mood and cognitive performance. However, to date there are no studies assessing the effect of matcha tea itself. The present study investigates these effects by means of a human intervention study administering matcha tea and a matcha containing product. Using a randomized, placebo-controlled, single-blind study, 23 consumers participated in four test sessions. In each session, participants consumed one of the four test products: matcha tea, matcha tea bar (each containing 4 g matcha tea powder), placebo tea, or placebo bar. The assessment was performed at baseline and 60 min post-treatment. The participants performed a set of cognitive tests assessing attention, information processing, working memory, and episodic memory. The mood state was measured by means of a Profile of Mood States (POMS). After consuming the matcha products compared to placebo versions, there were mainly significant improvements in tasks measuring basic attention abilities and psychomotor speed in response to stimuli over a defined period of time. In contrast to expectations, the effect was barely present in the other cognitive tasks. The POMS results revealed no significant changes in mood. The influence of the food matrix was demonstrated by the fact that on most cognitive performance measures the drink format outperformed the bar format, particularly in tasks measuring speed of spatial working memory and delayed picture recognition. This study suggests that matcha tea consumed in a realistic dose can induce slight effects on speed of attention and episodic secondary memory to a low degree. Further studies are required to elucidate the influences of the food matrix.

1. Introduction

The belief in the positive effects of food on health and well-being has existed for thousands of years; however, the interest in the scientific evidence about food and nutrients, which improve consumers' mood, and physical and mental performance has only emerged in the last decades (Prasad, 1998).

Many cognition and mood enhancing components present in food have already been studied. Matcha or matcha tea is becoming a frequently requested product by consumers and research has been conducted about its various positive health effects (Townsend, Maitin, Chesnut, & Vattem, 2011).

Matcha tea contains high amounts of polyphenols, free amino acids, particularly L-theanine, and caffeine, since, rather than just the tea extract, the tea leaves themselves are ingested as well (Weiss & Anderton, 2003). The tea plant *Camellia sinensis* is grown in mild climatic and shaded conditions. Three to four weeks before the harvest, the plants are 90% shaded, which enhances the tea quality by increasing the maturing period. 80% of total polyphenols in green tea are catechins and 59% of total catechins consist of EGCG, making EGCG the most prevalent and bioactive polyphenol in green tea (Cooper, Morré, & Morré, 2005; Dubick & Omaye, 2007; Koo & Noh, 2007). The percentage share of epigallocatechin gallate (EGCG) of the total catechins in matcha is proportionally higher than the share of EGCG present in Sencha, a commercial green tea grown in sunlight (Turkmen, Sarı, & Velioglu, 2009). Weiss and Anderton (2003) investigated the levels of catechins in matcha. The consumption of matcha tea, *i.e.* the ingestion of the matcha tea powder, resulted in an uptake of up to 137 times more of EGCG than the uptake of Chinese Green Tips green tea and three times more than any other recorded high quality green tea (without the ingestion of the tea leaves; Weiss & Anderton, 2003).

Due to its psychobiological effects, EGCG is one of the key constituents in matcha tea (Wightman, Haskell, Forster, Veasey, & Kennedy, 2012). Brown et al. (2009) found that green tea

* Corresponding author.
E-mail address: betina.piquerasfiszman@wur.nl (B. Piqueras-Fiszman).

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prepared from leaves high in EGCG improved the mood of middle-aged, overweight, and obese men after a treatment of eight weeks. Wightman et al. (2012) observed reduced heart rate and oxygenated hemoglobin levels and increased cerebral activity in case of a single treatment with 135 mg pure EGCG; however, they were not able to associate the results with any cognitive or mood changes. Scholey et al. (2012) investigated the effect of 300 mg EGCG and found it to increase calmness and reduce stress. Different effects have been observed at different doses. It was suggested that the effects occur in a dose-dependent manner (Scholey et al., 2012; Wightman et al., 2012). Comparing the administered doses to the amounts present in matcha tea, doses of 135–300 mg can be realistically consumed within normal diets. However, no replications of the study findings have been provided to date, making it difficult to determine conclusive effects of EGCG on mood and cognition. Many studies with rodents have investigated long-term effects of EGCG, providing reliable evidence for beneficial impact on cognitive functions (Chen et al., 2010; Wang, Chang, Soung, & Chang, 2012). However, the applied study designs differed considerably and it is questionable to what extent these results are relevant for mood and cognition effects in humans (Wolfram, 2007).

Besides EGCG, matcha tea includes L-theanine or 5-N-ethyl glutamine, a non-proteinogenic amino acid, which accounts for around 50% of the total amount of amino acids and is unique to tea (Hallock, 2005; Tan, Tan, Zhao, & Li, 2011; Thippeswamy, Gouda, Rao, Martin, & Gowda, 2006). Investigations applying electroencephalography (EEG) measurements were able to show effects after the ingestion of 50–100 mg L-theanine, namely reducing tonic α–levels and increasing the power in the α-1 frequency band (Kelly, Gomez-Ramirez, Montesi, & Foxe, 2008; Nobre, Rao, & Owen, 2008). These effects were associated with increased sustained attention processing and arousal levels (Barry, Clarke, & Johnstone, 2011; Einöther & Martens, 2013; Gomez-Ramirez, Kelly, Montesi, & Foxe, 2009). Doses below 100 mg L-theanine were not sufficient to detect effects assessed by subjective mood ratings or cognitive test batteries. Studies administrating higher doses (200–250 mg) found L-theanine having effects on mood and/or cognition, mainly on short-term (8–20 s) and long-term (up to 20 min) sustained attention, alertness, suppression of distracting information, mental fatigue, relaxation, and anxiety (Gomez-Ramirez et al., 2007; Gomez-Ramirez et al., 2009; Rogers, Smith, Heatherley, & Pleydell-Pearce, 2008).

Caffeine is the main bioactive component of matcha tea after EGCG and L-theanine. It is the most widely consumed stimulant worldwide. Depending on the type and preparation of tea, one cup contains between 35 and 250 mg caffeine (Christopher, Sutherland, & Smith, 2005; Einöther, Martens, Rycroft, & De Bruin, 2010; Smith, 2002). Already low quantities such as 40–75 mg were found to induce significant effects on mood and cognition (Einöther et al., 2010; Haskell, Kennedy, Wesnes, & Scholey, 2005). The compound is associated with improved performance, motivation, and concentration within a short period of time (Paulus et al., 2015). Caffeine was also found to increase EEG-α-frequency and blood pressure and decrease resting state cerebral blood flow (Barry et al., 2005). The studies consider a range of cognitive measures, such as speed of information processing, and executive control, on a variety of simple and higher-order processing tasks involving active monitoring, task switching, and response inhibition or interference. The most often observed effects in these tasks are improved alertness, sustained attention or vigilance, information processing, increased arousal state, and decreased mental fatigue and occurred at different dose levels (Adan, Prat, Fabbri, & Sànchez-Turet, 2008; Brice & Smith, 2001; Haskell et al., 2005; Smith, Brice, Nash, Rich, & Nutt, 2003; van Duinen et al., 2005). The outcomes of these tasks confirmed the results of physiological measures. Caffeine was found to increase heart rate, blood pressure and brain activity while participants were performing demanding tasks as well as in resting state (Barry et al., 2005; Barry et al., 2007; Barry et al., 2011; Childs & de Wit, 2006; Mitchell et al., 2011).

Comparatively, fewer effects of caffeine have been observed on participants' mood. The majority of studies observed global mood effects (Childs & de Wit, 2006; Smith, 2009) and significantly increased feelings of vigour and tension (Giles et al., 2012; Judelson et al., 2005; Tieges, Snel, Kok, & Ridderinkhof, 2009). It is noticeable that participants' mood deteriorated as the administered caffeine dose increased. This turnaround effects appeared mainly at a dose of 400–450 mg caffeine (Attwood, Higgs, & Terry, 2007; Brunyé, Mahoney, Lieberman, & Taylor, 2010; Childs & de Wit, 2006).

Only few studies are available investigating the direct effect of tea containing naturally occurring caffeine and have simultaneously been successful in the attribution of the observed effects on mood and cognitive performance to the individual constituents of the tea. Several intervention studies provide evidence that L-theanine acts in combination with caffeine and enhances the performance in high-level cognitive activities, attention, and mood (Camfield, Stough, Farrimond, & Scholey, 2014). L-theanine was also found to have an antagonistic effect on caffeine by decreasing arousal and lowering the blood pressure (Bryan, 2008; Dodd, Kennedy, Riby, & Haskell-Ramsay, 2015; Rogers et al., 2008; Vuong & Roach, 2014). Already low doses of caffeine appear to induce stronger detectable effects compared to L-theanine, as for instance shown by the outcome of the meta-analysis of Camfield et al. (2014). The administration of caffeine provided much greater predicted effect sizes for dimensions of mood such as alertness and calmness compared to the administration of L-theanine. This makes it difficult to transfer effects induced by matcha tea to L-theanine and caffeine individually since the amount of caffeine present in matcha tea is approximately twice as high compared to L-theanine (Aucamp, Hara, & Apostolides, 2000; Kakuda, 2002). The majority of intervention studies investigating effects on mood and cognition administered ratios of L-theanine/caffeine in the ratio of 2 to 1 in favour of L-theanine (Einöther et al., 2010; Yoto, Motoki, Murao, & Yokogoshi, 2012). These ratios are unrealistic with regard to the consumption of matcha tea and tea in general since a realistic ratio in tea is 2 to 1 in favour of caffeine (Dodd et al., 2015).

Only few intervention studies have been published employing tea as such or a realistic caffeine/L-theanine/EGCG ratio measuring effects on mood and cognitive performance. Moreover, these studies focus on late-life cognitive decline or age-related changes in hippocampus rather than on acute effects on mood and cognition in the adult healthy population (Borgwardt et al., 2012; Zhang, Zhang, Zhou, Ling, & Wan, 2013). Zhang et al. (2013) conducted an intervention study with 74 healthy participants treated with 400 mg green tea extract or a placebo three times per day for a period of five weeks. This dose of green tea powder corresponded to 20 mg caffeine per day. Zhang et al. (2013) found the green tea powder to increase reward-learning abilities and prevent depressive symptoms. However, although the treatment and the preparation of treatment appears to be comparable to matcha tea powder, the quantities of constituents differ materially. Matcha tea contains 7–10 times more EGCG and 5–6 times more caffeine (Ujihara, Hayashi, & Ikezaki, 2013). De Bruin, Rowson, Van Buren, Rycroft, and Owen (2011) investigated the effect of black tea on attention and self-reported alertness. Two studies were conducted administering caffeine/theanine rations of 100 mg/46 mg (study 1) and 90 mg/36 mg (study 2) per test session. The outcome of both studies indicated that black tea improves the ability to focus attention on a switch task and inter-sensory-attention test, but does not improve the ability to switch between task rules. The results were more pronounced for the participants in the black tea condition with higher quantities of caffeine and theanine suggesting that the observed effects might have been dependent on tasks and ratios since other studies found lower quantities of caffeine to improve performance in tasks requiring attention (Camfield et al., 2014). Moreover, it was observed that the performance on tasks was strongest towards the end of the test sessions. The outcome of the tasks together with the self-reported decreased levels of calmness, have been attributed to caffeine present in black tea counteracting