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Exploring the Health Benefits of Matcha: A Comprehensive Review

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Abstract:

Introduction: Matcha, a finely powdered form of green tea, has recently gained global popularity due to its vibrant green color, distinctive taste, and versatile applications in various food products. Despite its promising nutritional profile, matcha has not received significant attention in the academic community compared to traditional green tea.

Purpose of work: The primary objective of this review is to provide a comprehensive overview of the current understanding of matcha's biological properties and its potential health benefits.

Methods and materials: A review of the literature available in the PubMed database and Google Scholar, the

following keywords were searched: "matcha", “catechin", "EGCG", “cognitive function”, “green tea”

State of knowledge: Existing studies have demonstrated that matcha exhibits anticancer properties, enhances cognitive function, improves cardio-metabolic health, and modulates the gut microbiome. Moreover, matcha is known for its anti-inflammatory and antioxidant properties.

Summary: This review summarizes the latest research findings on matcha green tea and its potential health benefits. While animal studies have shown promising results, our knowledge of matcha's effects on human health remains limited. Further randomized controlled trials are necessary to fully elucidate its potential health-promoting effects. Therefore, we advocate for continued research into matcha's properties and its integration into dietary practices to promote overall health and well-being.

Keywords: catechin; cardiovascular health; cognitive function; matcha; anti-tumor response

Introduction

Tea is the second most popular beverage after water. The two main types of tea are black and green, with black being fermented and green not [1]. Green tea has been known for centuries for its health-promoting properties. It offers notable advantages, such as its antioxidant properties, ability to inhibit bacterial growth, and potential anti-cancer effects. Additionally, it enhances cardio-metabolic health, cognitive function and helps to control body weight [2].

Recently, matcha, a powdered form of green tea, has been gaining popularity. It is used across diverse sectors of the food industry, serving as both a dietary supplement or as an ingredient

in various food manufacturing establishments. It is frequently used as a culinary component in cakes, ice cream, and noodles [3,4,5].

Matcha cultivation

Although matcha comes from the same Camellia sinensis plant as regular green tea, it is cultivated and processed in a different way, making the concentration of bioactive compounds higher than in other types of green tea. The tea plants are intentionally shielded from sunlight for approximately 20–30 days before harvesting. The shading process slows down the photosynthesis in leaves and triggers a rise in chlorophyll levels, giving the leaves a deep green color. Following this, only the highest-quality young tea leaves are carefully chosen and promptly steamed briefly to halt oxidation [3,4,5]. Subsequently, their stems, veins, and any impurities are removed and stone-ground into a fine, bright green powder [4].

Matcha tea preparation

Being a Japanese traditional beverage, matcha is typically prepared using time-honored methods. The tea is measured with a bamboo spoon and added into a tea bowl, called a chawan. Traditionally, water of about 70 degrees Celsius is poured into a bowl, and the mixture is whisked using a special bamboo whisk known as a chasen until it achieves a smooth, frothy consistency [4,6]. Recently it was indicated that infusions prepared at 90°C are the most abundant in bioactive compounds such as polyphenols and vitamin C and have higher antioxidant potential. In addition, matcha from the second and third harvests seems to be the most beneficial for health [7]. Due to the shielding of matcha tea plants by bamboo fabrics for most of their growth, they boast prominent levels of theanine, amino acids, and caffeine, alongside a lower concentration of catechin. This unique composition and high concentration give matcha its distinctive "Umami" taste, which harmonizes with the typical bitterness of tea. In contrast, tea plants grown in sunlight tend to have higher levels of catechins, intensifying the bitter flavor [4, 6, 8, 9, 10, 11, 12]. However, when dissolved in water, matcha shows an increase in catechins compared to its loose-leaf counterpart in green tea [13]. Due to the specific style of consumption matcha tea requires complete ingestion of the leaf, providing more health benefits [14].

Chemical composition

Matcha is abundant with a multitude of biologically active ingredients with anti-inflammatory and antioxidant properties, including various catechins, theanine, caffeine, chlorophyll, phenolic acids, rutin and vitamin C. Chlorophylls, insoluble dietary fibers, proteins, and fat-soluble vitamins make up 60-70% of matcha, being the insoluble components of matcha.

While the remaining 30-40% are caffeine, water-soluble vitamins, water-soluble fibers, saponin, amino acids, minerals and polyphenols. The nutrient composition fluctuates in accordance with the timing of harvest, as well as the brewing temperature employed. The remarkable health-promoting attributes of matcha green tea predominantly stem from the presence of polyphenolics and phytochemicals, especially catechins [5,7,15]. Catechins are a natural type of phenolic compounds known for its antioxidant potential, greater than vitamin C, flavonoids and glutathione [16]. Four most significant catechins of matcha are (−)-epicatechin (EC), (−)-epicatechin-3-gallate (ECG), (−)-epigallocatechin (EGC) and (−)-epigallocatechin-3-gallate (EGCG). EGCG is the most extensively investigated catechin in relation to its health benefits, recognized for its predominant abundance and high activity [17].

Health benefits of matcha

The consumption of matcha due to its potent biological compounds offers numerous health benefits to the human organism. The most crucial include anticancer properties, the positive effect on cognitive function and improving the overall cardio-metabolic and gut health [2,8]. Furthermore, matcha has an anti-inflammatory and antioxidant effect. In a study by Ramirez et al. on Schistosoma mansoni-infected mice, matcha downregulated inflammation markers such as TNF-α, IFN-γ, IL-13 and elevated level of IL-10 [18]. Moreover, matcha can even inactivate SARS-CoV2 virus, including the Omicron subvariant [19,20].

Cognitive function

Green tea consumption has been linked to decreased risk of neurodegenerative diseases and improvement of cognitive function [15,21]. The bioactive compounds in matcha, notably catechins, along with caffeine, and theanine are acknowledged for their beneficial impact on cognitive function [5]. EGCG can serve as a neuroprotective agent due to its ability to control the inflammatory process involved in neurodegeneration and enhance cognitive function [15,21]. Furthermore, it has been indicated that EGCG can inhibit the coaggregation of amyloid proteins, including amyloid-β (Aβ) and human islet amyloid polypeptide, which take part in pathogenesis of Alzheimer's disease [22]. It is suggested that green tea catechins, especially EGCG, may inhibit age-related cognitive decline by upregulating the expression of genes involved in synaptic plasticity in the hippocampus [23]. Research on caffeine and L-theanine intake showed a range of functional outcomes associated with mood, attention, mind-wandering, inhibitory control, and cognitive processes [24]. Studies suggested that caffeine may be neuroprotective against dementia and Alzheimer disease [25].

Human studies on cognitive function

In human studies, the intake of matcha has been proven to enhance cognitive function after stressful situations, in different age groups, and both short- and long-term. One of the first studies to describe the effect of match on cognitive faculties was conducted by Dietz et al. This research has furnished evidence suggesting that matcha may enhance working memory, performance in tasks requiring vigilance or sustained attention, and psychomotor speed in response to stimuli. However, no change in mood of participants was observed [26]. Cognitive function may diminish as a result of psychological stress. A randomized placebo-controlled study by Baba, Kaneko and Takihara aimed to determine if intake of matcha improves the attentional function of young adults after mild acute stress. Results in the matcha group showed significant reduction in reaction time and increase in the number of correct hits for positive emotion in perception of emotions test. However, drinking matcha did not increase participants' energy levels, concentration, or thinking ability. It also did not lessen their level of fatigue [27]. Baba, Ingaki et al. in a different study compared effects of matcha, caffeine and placebo in single and continuous intake. The aim of this study was to investigate whether caffeine plays a significant role in matcha's efficacy in enhancing cognitive function and to assess whether matcha aids in the preservation of cognitive functions following mild acute stress. Research was conducted on groups of middle-age and older. After a single matcha dose, there was a decrease in reaction time in cognitive function tasks, which was probably caused by caffeine. Matcha showed better results than caffeine in work performance. Additionally, continuous intake was more beneficial in the matcha group [28]. Sakurai et al. also studied matcha’s impact on cognitive function of elderly people. However, significant change was only observed in the female subgroup regarding their language domain of cognitive function [29].

Animal studies on cognitive function

Several animal studies have investigated the impact of matcha tea on cognitive function. Iwai et al. Iwai et al. reported that long-term matcha consumption has a protective effect on capillary aging in the brain cortex. It suggests that matcha has a positive impact on brain function [30]. Kim et al. (2020) evaluated effects of matcha in reversing high-fat diet induced cognitive dysfunction on male mice. This study revealed that matcha improves cerebral cholinergic system, reduces neuroinflammation and protects against cognitive impairment [31]. The same research group in their next study assessed the anti-amnesic effect of matcha on mice with systemic inflammation induced by particulate matter (PM)2.5. Matcha improved

the cholinergic system of the brain and prevented cognitive dysfunction induced by air pollution by modulating systemic inflammation. It also ameliorated memory and learning function [32].

Stress reduction

It is suggested that matcha has a stress-reducing effect due to theanine content. Unno et al. tested matcha impact on mice with enlarged adrenal gland due to psychosocial stress. Matcha consumption resulted in dose-dependent suppression of adrenal hypertrophy, indicating the stress-reducing effect of matcha. It was also emphasized that quality serves as a critical determinant of matcha's efficacy. In the second part of this study, the effects of daily consumption of 3 grams of matcha were investigated in healthy individuals. In comparison to the placebo group, this intervention resulted in a significant reduction in anxiety levels and a decrease in physiological stress [9]. Stress reduction was also observed in study with usage of cookies containing matcha formulated with specific ratio of components (epigallocatechin gallate to theanine and arginine). Harnessing the stress-reducing properties of matcha can be a novel and effective approach to supporting overall daily well-being [33].

Cardiometabolic health

In recent times, the consumption of matcha tea has been associated with remarkable cardio-metabolic outcomes and significant health advantages. Studies conducted by Zhou et al., Xu et al. and Wang et al. on mice demonstrate that Matcha green tea decreases hyperglycemia and enhances lipid profiles. It reduced the level of triglycerides, total cholesterol, as well as ALT, AST activities in mice fed a high fat diet. Therefore, matcha mitigates the progression of obesity, lipid accumulation, and hepatic steatosis [34, 35, 36]. Moreover, Zhou et al.'s research revealed that the levels of key inflammatory cytokines (TNF-α, IL-6, and IL-1β) linked to hepatic inflammation were markedly lower in the group of mice receiving matcha supplementation on a high-fat diet [34]. In the Xu et al. study the level of high-density lipoprotein-cholesterol (HDL-C) was elevated [35]. It is noteworthy that Wang et al. concluded that matcha supplementation in mice fed a high-fat diet resulted in morphological changes in liver tissue and a significant decrease in AST and ALT levels. These findings suggest that matcha may contribute to liver stability and alleviate metabolic disorders induced by high-fat diets. Moreover, in Wang’s study matcha intervention modified the gut microbiota in the high fat diet group of mice. It enriched the intestinal microbiome with Alloprevotella, a bacteria known for producing short-chain fatty acids, the presence of which was found to have

a negative correlation with non-alcoholic fatty liver disease [36]. El-Elimat et al. conducted a pilot observational study on overweight and obese individuals who followed a specified low-calorie diet plan for 12 weeks. The study group additionally received matcha tea once a day. The findings of the research align with those from previously mentioned animal studies. It was observed that in the matcha tea group the mean level of fasting blood glucose decreased from 91.0 to 85.2 mg/dL, while no significant change was observed in the control group. What is more, the study group showed a potential increase in HDL-C and decrease in insulin and leptin levels. Additionally, a significant increase in IL-10 was observed following matcha tea consumption. In conclusion the study suggests that matcha tea may have anti-inflammatory properties, along with a potential effect on weight loss due to its high content of phenolics and dietary fibers [37]. Additionally, Willems and Foster recently conducted a study on humans to evaluate the impact of matcha green tea on heart rate variability. Their findings suggest that matcha reduces heart rate during supine rest, indicating a modulation in parasympathetic nervous system activity and contributing to its relaxing effect [38].

Gut health

In recent years gut microbiota and its potential role in pathogenesis of various chronic diseases gained enormous popularity.

The homeostasis of gut microbiota has a crucial role in maintaining the immune balance, generating health promoting metabolites and preventing the invasion of opportunistic pathogens in the gut. This defense mechanism reduces the likelihood of triggering the host's immune response and inhibits autoaggression [39]. In recent years, many studies have been conducted to evaluate the potential correlation between dysbiotic intestinal microbiota and the occurrence and development of depression, inflammatory bowel disease, autism, Diabetes Melitus both type I and II [39, 40]. In comparison to regular green tea matcha is believed to have positive effects on gut microbiota due to its higher content of nutrients such as tea catechins and insoluble dietary fiber [41].

Morishima et. al conducted a randomized, double- blinded study on humans to investigate whether the consumption of matcha affects the composition of the gut microbiota. The study group was supplied with capsules containing 1.5g matcha each and prepared the drink using hot water. Participants from the control group were given capsules with placebo (fragrance and Gardenia pigment). All of the research subjects consumed the treatments for two weeks, then the feces from both groups were collected and compared with the samples obtained

before the intervention, using 16S rRNA metagenomic sequencing, The beta- diversity of microbial composition significantly changed in the matcha group. In their fecal microbiota scientists observed an increase of Coprococcus and a decrease of Fusobacterium. Researchers theorize that catechins and its metabolites present in matcha tea contributed to the depletion of Fusobacterium and that the insoluble fiber helped to increase the amount of Coprococcus bacterium. What is noteworthy, Fusobacterium is considered to be a harmful bacterium. It was observed in a high proportion in the gut microbiota in patients diagnosed with inflammatory bowel disease and colorectal cancer. In comparison, Coprococcus produces butyric acid, which is beneficial to the host's health. Hence, the authors concluded that the consumption of matcha in the long term may have beneficial effects on the gut microbiota composition [41].

Shigeta et al. in a recently published study have combined daily consumption of beverages containing 1.5g of matcha green tea powder and resistance training. Significant changes in bacterial taxa were found by metagenomic study of the gut microbiota after 4 weeks of matcha consumption. In the study group the abundance of Oscillospira, Ruminococcus and Butyricimonas was significantly higher than that before the intervention and positively correlated with the change in maximum muscle strength. However, the change was no longer observed at 8th week of the intervention. Further research will be required to explore the potential implications of matcha consumption on the gut microbiota [42].

Anticancer activity

Cancer is the second greatest cause of death globally, with both its incidence and mortality rates demonstrating a consistent upward trend over time [43].

To date, four in vitro studies on breast cancer cells and one in vivo study on an animal model have been conducted to assess matcha's potential antitumorigenic effect. All in vitro studies proved that matcha can inhibit viability of different types of breast cancer cell lines [44, 45, 46, 47]. Bonuccelli et al. indicated that matcha works by affecting mTOR signaling, especially downregulating many components of the 40S ribosome [45]. Keckstein et al. proposed that matcha exhibits anticancer properties attributed to its capacity to enhance the expression of PPARγ [47]. Moreover, matcha decreases expression of estrogen receptor-beta (ERβ) on MCF7 breast cancer cells. However, the underlying molecular mechanisms responsible for the effects of matcha on cellular viability remain unclear [44].

Sokary et al. aimed to assess matcha as an anticancer treatment by evaluating its impact on two zebrafish xenograft models for triple-negative breast cancer cell lines, MDA-MB-231 and

MDA-MB-468. Both cell lines exhibit high invasiveness and resistance to anticancer drugs. Optimal non-toxic dose of matcha was determined and used. A tendency towards a decrease in tumor mass size and metastatic potential was observed following exposure to matcha in a dose-dependent manner [43].

In conclusion, the available evidence suggests that matcha exhibits considerable anticancer potential. However, additional studies are required to investigate its effects on diverse cancer cell lines and to ascertain its long-term efficacy.

Conclusion

Numerous studies support the benefits of green tea, while comparatively few studies examined the properties of matcha. Matcha, a powdered high-quality green tea of Japanese origin, started gaining popularity only recently and knowledge on its effect on human health is still limited. Due to its specific process of cultivation and consumption of whole grounded leaves, this Japanese beverage is abundant with bioactive compounds that in multiple ways positively affects human organism.

In this review, we have summarized the latest research on matcha green tea and its health properties. Anti Inflammatory, antioxidant, anticancer, improvement of cognitive function, cardiometabolic health and potential positive effect on gut microbiome are some of the undeniable advantages of matcha consumption.

Despite the promising outcomes of animal studies, the state of knowledge on its effect on human health is still limited and more randomized controlled trials are needed to evaluate its full potential. Thus, we hope to encourage the scientific community to further investigate the properties of matcha and promote its inclusion in the diet.

Author's contribution:

Conceptualization, JJ, and AK; methodology, EW; software, KC; check, KC, AMK, AK and KB; formal analysis, EO; investigation, EW; resources, OS, KC, EW; data curation, OŁ, KS, AMK, KC, AK, JJ, OS, EO, EW, KB; writing – rough preparation, OŁ, KS, EW, AK, JJ; writing – review and editing, OŁ, KS, AMK, KC, AK, JJ, OS, EO, EW, KB; visualization, JJ and AMK; supervision, OŁ and KS; project administration, OŁ, KS, AK, OS, JJ;

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