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From Cup to Cure: The Impact of Matcha Tea on Alzheimer's Disease

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ABSTRACT

Alzheimer's disease (AD) is a progressive neurodegenerative disorder characterized by neurofibrillary tangles, amyloid beta aggregation, and neuronal dysfunction and loss. Research into various therapeutic approaches to prevent AD onset is a significant field of study as no definitive cure currently exists. Globally, studies recognize herbal therapies for their accessibility, affordability, and health-promoting properties against neurodegenerative diseases. Matcha tea in particular, from the *Camellia sinensis* plant, comprises of components such as epigallocatechin-3-gallate (EGCG), caffeine, L-theanine, rutin, and quercetin which possess several anti-AD health-promoting properties. However, further research into the effects of individual components in matcha towards specific diseases is valid and required. Therefore, this study synthesized a comprehensive assessment of the specific AD-associated factors that matcha tea exhibited beneficial effects towards. The research methodology consisted of a secondary review and analysis of peer-reviewed research articles and primary sources. Epidemiological studies were utilized to investigate the various mechanisms that individual components in matcha employed against AD pathology and hallmarks. The research was compiled into a table demonstrating which components in matcha were associated with alleviating certain AD-associated factors. Finally, the practical applications of matcha and future considerations in the field were discussed. The results indicated that matcha's components beneficially affected numerous AD hallmarks and employed various mechanisms to mitigate AD symptoms. Based on the results, it was concluded that matcha possesses several anti-AD health-promoting properties that may supplement and amplify current prevention strategies. Therefore, this study recommends matcha consumption as a preventative measure against AD.

Introduction

In many countries, tea is one of the most consumed beverages aside from water. Individuals can purchase green tea in many forms including loose-leafed, powdered, and condensed. Matcha tea, a powdered version of Japanese green tea, is made from the *Camellia sinensis* plant (Sakurai et al., 2020). Many regard matcha as the highest quality tea due to its unique flavor and chemical composition. However, the direct impacts of the components in matcha tea have not been adequately explored. Therefore, research into the effects of matcha consumption and its individual properties against specific diseases requires further exploration (Kochman et al., 2021). Epidemiological studies link tea consumption to a reduction in the risk of developing Alzheimer's disease. Alzheimer's disease (AD), a neurodegenerative disorder characterized by amyloid-β (Aβ) senile plaques in the brain, is the sixth leading cause of death and the second leading health concern among adults. AD prevention through non-pharmacological treatments is essential as no definitive cure currently exists (Polito et al., 2018). Therefore, one of the few options to decrease AD onset is intervention methods into individuals' daily habits. Nutritional intervention is a growing field of study in this regard (Sakurai et al., 2020). Although there are a variety of prevention strategies against AD promoted by the media and consumed by the public, there is not sufficient evidence yet to make broad public health recommendations (Carman et al., 2014). Thus, in order to fully validate recommending matcha consumption for its beneficial health properties, deeper research

into its effects on AD is necessary. Therefore, this study aims to address the question: how do the components in matcha tea act as a preventative measure and way to mitigate symptoms of Alzheimer's disease?

Researchers Kakutani et al. (2019), from the Research Institute at Suntory World Research Center in Japan, conclude that green tea catechins demonstrate neuroprotective effects against factors that characterize AD such as anti-inflammation, anti-oxidative stress, anti-apoptosis, and inhibition of Aβ aggregation. Similarly, researchers Shi and Zhao (2024) note that the consumption of bioactive compounds such as epigallocatechin-3-gallate (EGCG) in matcha may prevent tau-related pathology development, a significant pathological hallmark of AD. Thus, researchers recognize the neuroprotective benefits of matcha consumption.

The debilitating nature of AD poses substantial societal and economic burdens on the healthcare system. The estimated healthcare costs associated with AD are projected to exceed USD 1 trillion by 2050 (Skaria, 2022). Notably, researcher Skaria (2022), the Director of Clinical Pharmacy Services at Centene Corporation in Florida, suggests these findings underestimate the indirect costs of AD. Rather, tea consumption provides an affordable prevention strategy.

Researchers Carman et al. (2014), from the Alzheimer's Drug Discovery Foundation in New York, highlight that successful prevention approaches against AD need to be highly safe because they target healthy individuals prior to disease onset. In acknowledging the safety aspect, matcha tea is a promising choice. Thus, further research into the properties composing matcha tea could be beneficial as a potential prevention method against AD.

Given the inexplicable correlation between matcha tea and Alzheimer's disease, daily matcha consumption could help prevent disease and promote body health. Tea consumption is an easy lifestyle adjustment that could make a significant impact. The accessibility, widespread use, and cost of matcha tea make it a strong preventative measure to combat a detrimental disease. Hence, a comprehensive review of the properties of matcha tea which may alleviate and prevent AD is valuable.

Methodology

The primary objective of this research was to synthesize a comprehensive assessment of the components in matcha tea that could play a beneficial role as a preventative measure against Alzheimer's disease. The research methodology consisted of a secondary review and analysis of peer-reviewed research articles and primary sources. The research was qualitatively assessed and specific components of the tea were chosen to highlight in the paper. ShiThis process included reviewing numerous primary peer-reviewed research studies regarding the mechanisms the components in matcha employ in combating AD. The correlation between matcha and AD was further explored by separating individual components in matcha and utilizing primary sources to gather research on the specific functions of each respectively against AD. Then, through the research synthesized, conclusions were drawn on the potential roles of catechins, EGCG, caffeine, L-theanine, rutin, and quercetin towards AD. After reviewing specific compounds, a broader approach was utilized to analyze the relationship between matcha and neurological diseases as a whole. Finally, the research was focused in regards to the practical applications of matcha and future considerations in the field. This study was conducted solely with data and analysis from online resources. No physical tools or materials were used in the research. Thus, no ethical considerations were observed. Research bias was reduced by gathering sources from numerous countries and continents globally. Likewise, sources aimed at testing various objectives were employed in order to avoid narrow perspectives and offer differing analysis methods to highlight the different properties of matcha.

Understanding Alzheimer's Disease

In 1906, Dr. Alois Alzheimer examined amyloid plaques and neurofibrillary tangles in the brain tissue of a woman who died from what was regarded as a mental illness at the time. Eventually, scientists recognized this mental illness as Alzheimer's disease. The National Institute on Aging (2023) defines AD as a brain disorder that slowly impairs cognitive functions, including memory and coherent thinking. As the disease progresses, it becomes strenuous to carry

out the simplest of tasks. Researcher Ribarič (2018), from the Institute of Pathophysiology in Slovenia, projects the global number of AD patients to exceed 140 million by 2050, and notes that AD is the most common cause of dementia. By 2050, it is projected that 18.9 million individuals in Europe and 36.5 million in East Asia will have dementia (Hampel et al., 2021). In the United States, AD is extremely prevalent with an individual developing the disease every 67 seconds (Geiser et al., 2017). According to the Alzheimer's Association (2024), of the total United States population, approximately 1 in every 9 individuals aged 65 or older has AD dementia.

Dementia hinders cognitive and behavioral abilities, interfering with an individual's daily life. Dementia has several stages with varying severity levels. The lowest severity level affects an individual's basic functioning abilities, and the most severe stage renders the person completely dependent on others to perform basic activities (National Institute on Aging, 2023). AD progresses from mild cognitive impairment (MCI) to a full AD onset. The rate of MCI to dementia is approximately 10% each year with the reversion rate being 24% (Sakurai et al., 2020). Given the projected prevalence and impact of AD, it is imperative to develop effective therapeutic approaches to mitigate this global health crisis.

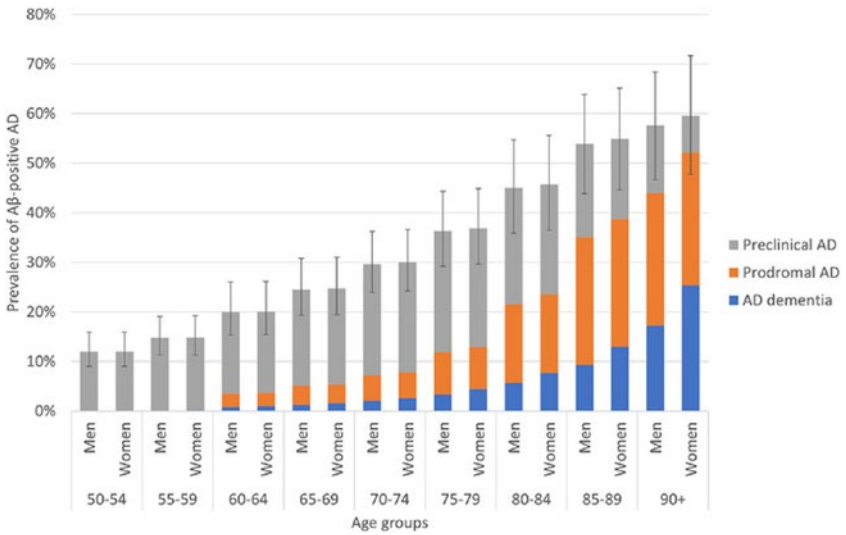

Figure 1. Prevalence of Aβ-positive AD Across the Alzheimer's Continuum. Reference: Gustavsson et al., 2022. Description: Estimated by age, stage, and sex, this data shows the prevalence of Aβ-positive AD across the Alzheimer's continuum with the assumption that 70% of general dementia had a clinical AD diagnosis.

AD involves brain areas related to memory, language, and thought. Common symptoms of AD include impaired judgment, memory loss that disrupts daily activities, misplacing items and difficulty retracing steps, challenges in completing familiar tasks, and trouble managing finances. A common approach to AD treatment includes delaying and slowing disease symptoms (Centers for Disease Control and Prevention, 2020). AD leads to the loss of neuronal connections in the brain, impairing the transmission of signals between the brain and the rest of the body. Changes in the brain prior to AD onset may occur a decade before symptoms begin to appear. In this early stage, neurons lose connection with each other, stop functioning, and die. Abnormal protein build-ups are common as well. While the scientific community has made substantial progress in understanding AD, scientists do not fully understand the exact causes yet. Salehi et al. (2016) suggest that between 40% to 80% of individuals with Down syndrome will develop AD by the fifth to sixth decade of life. Scientists believe a combination of several genes, environmental factors, and lifestyle influence AD (National Institute on Aging, 2023). Thus, exploring and understanding the various factors that affect AD may provide insight into mechanisms and therapeutic approaches to mitigate the symptoms.

Researchers Hardy and Higgens (1992) posit that Aβ deposits in the brain initiate AD pathogenesis. These deposits result in tau tangle formation, cognitive decline, and neuronal dysfunction and loss. In the early clinical

stages, researchers dedicated considerable attention and effort to developing therapeutic compounds that target the Aβ pathway, aiming to slow AD progression. This focus stems from studies identifying the Aβ pathway as a hallmark of AD pathology (Hampel et al., 2021). Scientists consider Aβ as the prominent force in AD's pathological processes with the "amyloid cascade hypothesis" emerging as a leading subject of research. Aβ aggregates play a causative role in AD development and provide a future avenue for AD modification. However, most Aβ-targeting drug trials fail due to a lack of accurate translational models, Aβ physiological homeostasis loss, and a lack of sufficient specificity (Zhang et al., 2023). Therefore, it is essential to explore alternative methods for targeting Aβ production and accumulation beyond traditional drug trials. Accordingly, Kim et al. (2020) observed that matcha consumption led to decreased levels of expressed Aβ. Thus, exploration into the potential of matcha tea may offer insight into future therapeutic approaches in combating AD.

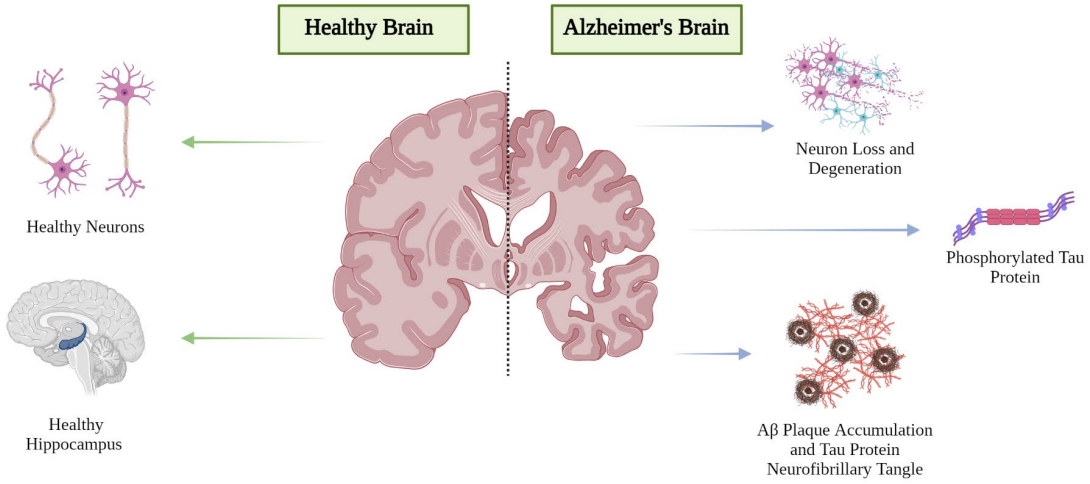

Figure 2. Healthy Brain versus Alzheimer's Brain**.** Created By: Adhiti Parupalli with BioRender.com. Description: A healthy human brain consists of healthy neurons and a well-functioning hippocampus. The AD brain is shriveled and consists of neuronal degeneration and loss, phosphorylated tau proteins, tau protein neurofibrillary tangles, and Aβ plaque accumulation.

Discussion of Herbal Medicine

Plants contain a variety of beneficial compounds with antioxidant properties. Approximately 200 years ago, scientists harnessed opium from the poppy *Papaver somniferum* seed pods to invent morphine. Similarly, Alexander Fleming later discovered the benefits of penicillin. These discoveries sparked the trend of producing products from natural sources and plants which significantly contributes to commercial drug products today (Wachtel-Galor & Benzie, 2011). Researchers Khan et al. (2023) claim that the emerging field of utilizing medicinal plant therapies to treat neuroinflammation can target various AD pathological issues. Therefore, exploring the history and global spread of herbal practices can demonstrate the practicality of therapeutic approaches.

While chemically synthesized drugs have revolutionized healthcare in the last century, many developing countries still depend on traditional medicinal practices. In India, 70% of the population depends on herbal medicine, and similarly, in Africa, up to 90% of the population depends on traditional medicine to meet their healthcare

requirements (Wachtel-Galor & Benzie, 2011). In sub-Saharan Africa, the South African Ministry of Health recommends two African herbal compounds for HIV management. The ministry approves *Hypoxis hemerocallidea*, also known as the African potato, and *Sutherlandia* for HIV and AIDS treatment (Mills et al., 2005). Aside from developing countries, in developed ones, pharmacies sell herbal extracts, teas, and essential oils alongside conventional drugs. According to Bhat et al. (2021), in both developed and underdeveloped countries, more than 75-80% of individuals trust herbal medicine remedies for their healthcare. Thus, given the prominence of herbal therapy across the globe, research into the effects of traditional therapies on neurodegenerative diseases may be insightful.

Individuals gravitate towards traditional medicine for various reasons, including affordability, concerns about synthetic medicine side effects, and increased access to health information. The versatility of plants and herbs allows individuals to process them into teas, syrups, salves, capsules, tablets, rubs, and ointments. Plants themselves contain a variety of beneficial compounds with antioxidant properties (Wachtel-Galor & Benzie, 2011). Scientists derive natural components from various sources such as grapefruits and oranges. Khan et al. (2023) note that research into herbal medicine therapeutics regarding numerous neurological diseases and conditions including AD, Parkinson's disease, epilepsy, Huntington's disease, and Amyotrophic Lateral Sclerosis (ALS) could be beneficial. Hence, innovations and advancements in this field could offer an effective and unique approach to targeting severe neurological diseases.

The Benefits of Matcha Tea

Green tea accounts for 25% of global tea sales (Baba et al., 2021). In 2016, global tea production amounted to 5.7 million metric tons (Valavanidis, 2019). To illustrate this quantity in context, two-thirds of the world's population consumes tea made from the *Camellia sinensis* plant (Khan & Mukhtar, 2013). Consequently, an examination of the various components in matcha, a specialized form of green tea, provides valuable insights into a widely consumed market. Matcha tea has a unique taste with a rich umami flavor (Sokary et al., 2022). Researchers Kochman et al. (2021), from the Department of Human Nutrition and Metabolomics at Pomeranian Medical University in Poland, report that shading the *Camellia sinensis* plant during growth increases the accumulation and synthesis of biologically active compounds such as caffeine, theanine, and catechins. To enhance the production of bioactive compounds, amino acids, and the non-bitter taste of matcha, the Japanese traditionally use bamboo mats to shade tea bushes from excessive sunlight for most of the growth period (Kochman et al., 2021). The unique harvesting and farming process of matcha tea produces a higher concentration of bioactive compounds compared to other types of green tea. Researchers Sokary et al. (2022) regard matcha as a high-grade green tea due to elevated levels of caffeine and amino acids. Thus, matcha's widespread consumption and its distinctive properties contribute to its broad public appeal.

Furthermore, researchers Sakurai et al. (2020), from the Department of Integrated Biosciences at the University of Tokyo in Japan, report an increase in the consumption of tea and tea extract supplements due to growing recognition of their health benefits. These benefits include lower blood pressure, decreased stroke risk, and improved neuroprotection and psychopathological symptoms. Notably, researchers found that individuals with existing psychopathological symptoms experienced improvements in stress relief and anxiety following green tea consumption. Moreover, Camfield et al. (2014), researchers from the Centre for Human Psychopharmacology at Swinburne University in Australia and New Product Research in the United Kingdom, report that epidemiological studies link tea consumption to various brain health benefits including a reduction in cognitive decline incidences. Matcha further improves the function of the cholinergic transmission system in the brain which is strongly correlated with cognitive function. Additionally, matcha exhibits a significantly greater protective effect against oxygen radicals than normal tea leaves (Sokary et al., 2022). Iwai et al. (2021) suggest that matcha tea intake supports neuron density in the brain cortex which preserves vascular health, thereby protecting brain function. Matcha has several special characteristics that allow it to provide double the amount of fat-soluble nutrients including lutein and vitamin K in each serving. Sakurai et al. (2020) link some of these nutrients to an improvement in cognitive function. According to Kochman and colleagues (2021), matcha extracts and infusions may have practical applications in preventing premature aging

processes. Researchers Jiang et al. (2023) recommend a three-cup intake to reduce the risk of AD. Hence, researchers recognize the importance of harnessing matcha's benefits, and further exploration of its specific components and underlying mechanisms could be highly valuable.

The Roles of Catechins and EGCG

Matcha contains natural antioxidants, such as polyphenols, with catechins comprising 90% of these polyphenols. The main catechins are (−)-epicatechin (EC), (-)-epicatechin-3-gallate (ECG), (−)-epigallocatechin (EGC), and (-)-epigallocatechin-3-gallate (EGCG) (Sokary et al., 2022). These compounds occur naturally in tea bushes and offer numerous health benefits. Notably, matcha contains a higher quantity of catechins in comparison to black tea, oolong tea, and hōjicha (Kim et al., 2020). For instance, green tea contains approximately 5.46 to 7.44 mg/g of catechin content, whereas black tea contains 0 to 3.47 mg/g (Kochman et al., 2021). To develop a comprehensive understanding of matcha's role in preventing AD, a thorough review of catechins is essential.

The catechin epigallocatechin-3-gallate (EGCG), the most abundant and active compound in matcha, possesses strong anti-inflammatory and antioxidant properties and may also ameliorate cognitive defects (Sakurai et al., 2020). Kochman et al. (2021) attribute EGCG consumption in green tea to enhanced cognitive function and mental clarity. Moreover, EGCG reduces amyloid-β production in the brain which decreases neuroinflammation and prevents neurodegenerative-related neuropathologies such as AD (Kochman et al., 2021). EGCG has numerous benefits for AD, specifically concerning Aβ. For instance, Baba et al. (2021) associate Aβ peptide production with AD cognitive impairment. However, animal studies report that catechins suppress Aβ peptide production, underscoring their beneficial effects against AD. Similarly, EGCG inhibits Aβ accumulation which protects against Aβ toxicity (Sokary et al., 2022). Thus, EGCG's potential to reduce Aβ's production and accumulation may lead to promising therapeutic therapies.

Moreover, brain atrophy and neuronal death along with tau protein aggregation into fibrils result in AD. Therefore, tau fibril disaggregation may be a promising approach to combating AD. EGCG disaggregates tau and various other amyloid fibrils; however, its weak drug-like properties prevent it from fully penetrating the brain (Seidler et al., 2022). Nevertheless, Seidler et al. (2022) suggest that the EGCG molecule could be a plausible means to disassemble stable fibril structure in the brain, potentially leading to therapeutic treatments. Thus, EGCG in matcha posits numerous benefits against AD in regards to tau fibrils.

Furthermore, researchers Scholey et al. (2012) tested the effect of EGCG on brain activity and mood through a placebo-controlled, double-blinded, randomized crossover design study and found improved ratings of stress and calmness through electroencephalogram (EEG) results. The study also reported that EGCG affected signal transduction and cell survival in neurotoxicity models, demonstrating its neuroprotective effects on ischemia, Parkinson's disease, and AD (Scholey et al., 2012). This study demonstrates the extent of EGCG's functionality in not only AD but also other prominent and prevalent neurological diseases.

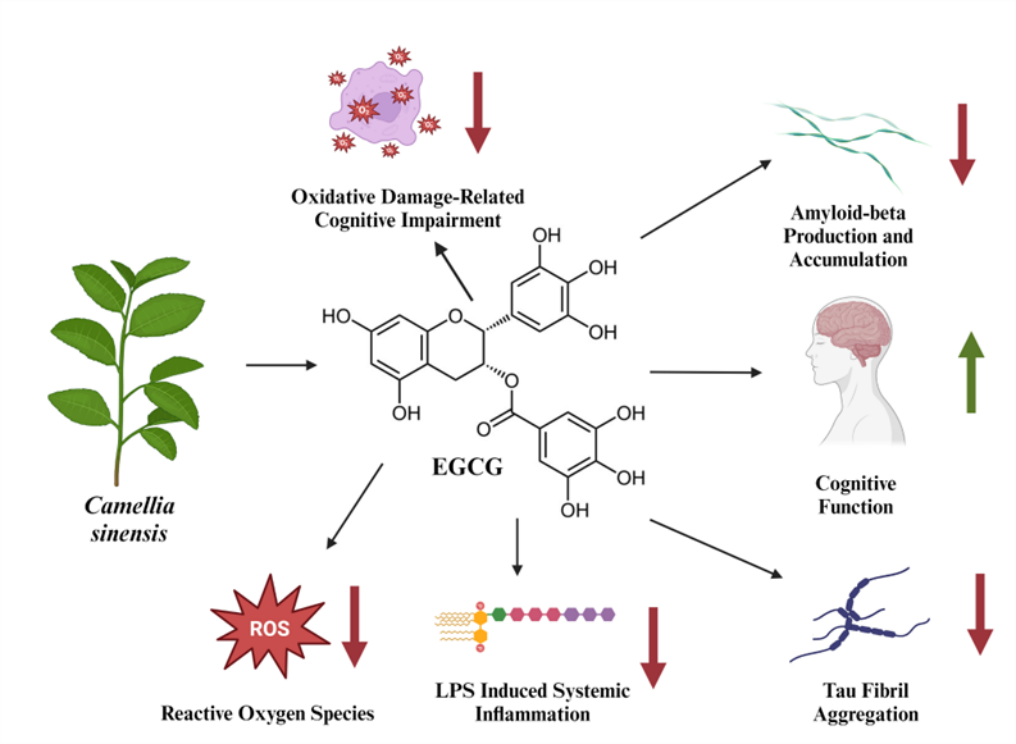

Figure 3. The Effect of EGCG on Alzheimer's Disease**.** Created By: Adhiti Parupalli with BioRender.com- EGCG image from Nagle et al., 2006**.** Description: EGCG is a component of matcha tea that has numerous effects on AD such as a reduction in oxidative damage-related cognitive impairment, Aβ production and accumulation, tau fibril aggregation, LPS-induced systemic inflammation, and reactive oxygen species (specifically H_2O_2). Additionally, it improves cognitive functioning abilities.

The higher content of unsaturated fatty acids in the brain compared to other tissues makes it more susceptible to oxidative stress. However, matcha's EGCG performs as an antioxidant function which can prevent oxidative damage-related cognitive impairment. Similarly, matcha protects the integrity of other antioxidant systems in the body including the liver and blood, further preventing cognitive impairment (Sokary et al., 2022). Additionally, lipopolysaccharides (LPS) induce systemic inflammation, playing a critical role in the development of neurodegenerative diseases. However, EGCG inhibits LPS reactive oxygen species (ROS) production. This function allows EGCG to actively work against neurodegenerative diseases (Kochman et al., 2021). Therefore, EGCG protects against oxidative damage, cognitive impairment, and ROS, assisting with AD prevention in the process.

Regarding cognitive decline, researchers Zhou et al. (2020) note that EGCG reduced neuroinflammation in the hypothalamus microglial cells, thereby lowering the risk of cognitive decline. Similarly, Unno et al. (2020) suggest that the catechins in matcha could increase the expression of genes related to the long-term plasticity of synapses and neuronal circuit change, thereby slowing age-related cognitive decline. Catechins positively influence cognitive decline and play an integral role in matcha's benefits against AD. Regular matcha consumption could be a significant source of catechins. Hence, researchers universally recognize the neuroprotective implications of matcha consumption and EGCG.

The Role of Caffeine

Several factors, including lifestyle, influence the deterioration of individuals' cognitive functioning with age. Caffeine, a purine-like alkaloid, is the most widely consumed psychoactive substance globally, exerting pleiotropic effects on multiple biological systems such as the immune, circulatory, and central nervous system (Carman et al., 2014). Baba et al. (2021) underscore extensive research on caffeine's effect on mood and performance. Regarding performance, caffeine inhibits the adenosine receptors A1 and A2A which increases dopamine transmission and acetylcholine in the brain, thereby heightening cognitive function and attention (Camfield et al., 2014). However, while caffeine may promote short-term improvements in attention, memory, and alertness, its ability to act as a prevention method against age-related cognitive decline is unclear (Carman et al., 2014). Therefore, future research should explore caffeine's impact on age-related cognitive decline to better understand the anti-AD potential of caffeine in matcha. In addition to these considerations, it is also crucial to note that caffeine reverses oxidative processes and reduces neuroinflammation which may indirectly inhibit brain aging (Kochman et al., 2021). This section addresses the effects of caffeine in matcha on AD.

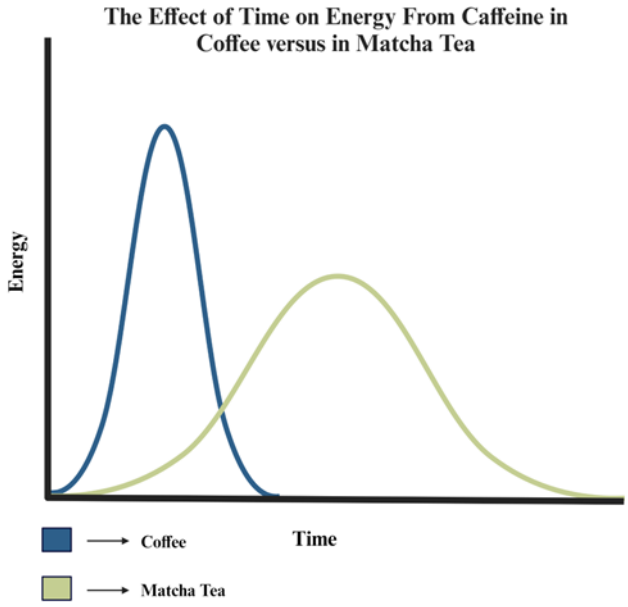

Figure 4. The Effect of Time on Energy from Caffeine in Coffee versus in Matcha Tea**.** Created By: Adhiti Parupalli with Biorender.com**.** Description: Matcha tea contains less caffeine than coffee per serving. However, the energy boost present after coffee consumption lasts for less time than matcha. Moreover, matcha does not lead to energy depletion like caffeine hours after consumption.

The caffeine content in green teas is approximately between 11.3 to 24.67 mg/g, while in matcha, the caffeine content falls within a range of 18.9 to 44.4 mg/g (Kochman et al., 2021). Matcha, with its higher caffeine content as compared to most green teas, provides a consistent caffeine intake. Therefore, the prominent caffeine content in matcha may contribute to its anti-AD effects.

According to Carman et al. (2014), AD mouse models demonstrate the neuroprotective potential of caffeine in neurodegenerative pathology. To elaborate, caffeine reduces Aβ production in mice harboring the amyloid-beta precursor protein (APP) transgenes and signals the adenosine A2A receptor. This effectively mediates beta-amyloid neurotoxicity in the hippocampus. Likewise, increased plasma caffeine levels in AD transgenic mice correlate with

reduced plasma Aβ levels (Carman et al., 2014). Dysregulation of Aβ levels in AD leads to senile plaques, which are significant as they contribute to neuronal activity alterations and synapse loss, resulting in cognitive decline (Anand et al., 2014). Hence, caffeine's functionality of decreasing Aβ production, neurotoxicity, and plasma Aβ levels suggests its potential in matcha for alleviating AD.

The Role of L-Theanine

Green tea contains theanine, a non-protein amino acid found solely in mushrooms and tea leaves. In animal studies, theanine demonstrated several anti-stress effects with enhanced learning abilities and behavior under stressful conditions after consumption. In a mice model, theanine improved cognitive functioning and neurogenesis in the developing hippocampus (Baba et al., 2021). This is especially important as researchers associate AD with decreased adult hippocampal neurogenesis (Gabarró-Solanas & Urbán, 2023). Researchers Gabarró-Solanas and Urbán (2023) consider promoting adult neurogenesis as a prospective therapeutic approach to AD-related cognitive decline. Future research should address the impact of theanine on neurogenesis in humans. In human studies, theanine consumption demonstrated a reduction in salivary immunoglobulin and heart rate as well as enhanced reaction rates and attention to cognitive tasks (Baba et al., 2021). Thus, scientists widely recognize the benefits of theanine consumption towards cognitive enhancement.

Moreover, theanine causes a positive downshift in neurodegeneration predominantly due to its similar structure with glutamate, the primary excitatory neurotransmitter in the brain, which enhances mood (Sokary et al., 2022). Researchers Crews and Masliah (2010) note that neurodegeneration characterizes AD. Therefore, theanine's ability to reduce neurodegeneration may play a role in AD. Additionally, scientists believe excitatory neuronal toxicity affects neurodegenerative diseases including AD (Walton & Dodd, 2007). However, theanine inhibits glutamine transport in astroglia and neurons, alleviating the excitotoxicity of glutamic acid in rat brains (Kakuda et al., 2008). Therefore, theanine's ability to counteract glutamic acid's excitotoxicity may contribute to its potential against AD.

L-theanine, the main amino acid in matcha tea, aids in reducing anxiety and may also modify early stress responses to prevent stress-induced brain atrophy. Sakurai et al. (2020) associate L-theanine with assisting in hippocampal long-term potentiation and alleviating symptoms of AD cognitive impairment in mice. These findings suggest that L-theanine's neuroprotective properties may be beneficial in AD treatment.

While theanine positively benefits cognitive function and neurogenesis independent of the other compounds present in matcha, its combination with caffeine can strengthen neurophysiological functions including attention (Sakurai et al., 2020). This combination also increases cholinergic and dopaminergic transmissions in the brain, enhancing cognitive function (Sokary et al., 2022). Similarly, Anas Sohail et al. (2021) report that the synergistic effects of caffeine and theanine pose significant enhancements in cognitive function clinically. Hence, theanine's functionality against AD, both independently, and in combination with caffeine, makes it a promising component in matcha for further exploration.

The Roles of Rutin and Quercetin

Anti-inflammatory potential and antioxidant effects characterize secondary plant metabolites known as phenolic acids. These acids have hypoglycemic and neuroprotective effects as well as the potential to prevent metastasis and inhibit cancer cell growth. The antioxidant capacity of green tea correlates with its phenolic content. Matcha tea, notably rich in the polyphenolic compound rutin, surpasses other teas in rutin concentration (Kochman et al., 2021). Jakubczyk et al. (2020) suggest matcha as a superior rutin source compared to other foods. For instance, buckwheat, a significant dietary rutin source, contains 62.30 mg/100 g of rutin, whereas matcha boasts 1968.8 mg/L. This high rutin content warrants further research into matcha's health benefits.

Its potent antioxidant and anti-inflammatory effects hold the potential for preventing certain neurodegenerative disorders (Kochman et al., 2021). In regards to AD, researchers Sun et al. (2021) tested the effect of rutin on a mouse model *in vitro* and discovered that it inhibited tau oligomer-induce cytotoxicity and tau aggregation, protected neuronal morphology from toxic tau oligomers, decreased proinflammatory cytokines production, and promoted microglial uptake of extracellular tau oligomers. Given that tau pathology hallmarks AD and neurodegeneration, rutin's dual targeting of tau and Aβ positions it as a promising candidate for AD treatment (Sun et al., 2021). As such, matcha's increased levels of rutin compared to other foodstuffs and rutin's beneficial effects on AD make it an essential component in battling the neurodegenerative disease.

Quercetin, a phytochemical in matcha tea with neuroprotective properties, enhances insulin sensitivity in tissues and regulates insulin secretion by normalizing carbohydrate metabolism. Interestingly, combining EGCG with quercetin may enhance the anticarcinogenic effects of both (Kochman et al., 2021). Schröder et al. (2019) measured the content of quercetin in an aqueous matcha extract and discovered that the content was 1.2 mg/mL which is marginally higher than the 1.1 mg/mL content in traditional green tea. In an experimental study regarding Parkinson's disease, quercetin protected against dopamine depletion and motor coordination. Likewise, in Huntington's disease, quercetin inhibited inflammation, microglial and astroglial activation, oxidative stress, and exerted neuroprotective effects (Khan et al., 2023).

Quercetin downregulates proinflammatory cytokines, thereby suppressing neuroinflammatory processes in AD. Researcher Sabarathinam (2024) identifies neuroinflammation as a hallmark of AD pathogenesis, highlighting quercetin's significance in combating AD. Moreover, at low micromolar doses, quercetin prevents oxidative stress-induced cell damage in neurons (Sabarathinam, 2024). Researchers Ionescu-Tucker and Cotman (2021) suggest that accumulated oxidative stress may be a critical mechanism in cognitive aging and AD. Thus, quercetin's ability to prevent oxidative stress further supports its role in AD prevention. Quercetin also inhibits Aβ aggregation and tau phosphorylation, both distinctive markers of AD pathology (Khan et al., 2019). Therefore, quercetin's inhibition of both makes it fundamental against AD.

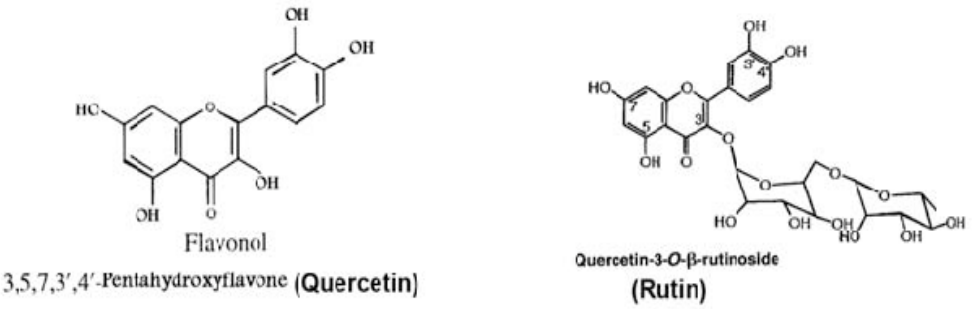

Figure 5. Different Molecular Structures of Rutin and Quercetin**.** Source: Saieed et al., 2006**.** Description: Quercetin is a flavonol with the chemical formula $C_{15}H_{10}O_7$. Rutin is a glycoside with the chemical formula $C_{27}H_{30}O_{16}$.

Results and Discussion

Matcha tea contains numerous components that mitigate AD symptoms and can be a promising therapeutic approach. This paper reviewed EGCG, caffeine, L-theanine, the combination of caffeine and L-theanine, rutin, and quercetin. To address the initial research question, which aimed to identify how the properties of matcha tea pose beneficial effects on Alzheimer's disease, a comprehensive literature review was conducted. Table 1 presents the study's synthesized findings, demonstrating the health-promoting properties and effects of the components in matcha against AD.

Table 1. Summary of Research on the Health-promoting Properties of Matcha Against AD

Anti-AD Health-Promoting Property	Component(s) Associated with the Effect	References
Anti-inflammatory and Antioxidant Properties	EGCG/Catechins	(Sakurai et al., 2020; Sokary et al., 2022)
	Caffeine	(Ruggiero et al., 2022)
	L-theanine	(Zhang & Tang, 2023)
	Rutin	(Pan et al., 2019; Kochman et al., 2021)
	Quercetin	(Khan et al., 2019)
Promotes Cognitive Function in AD	EGCG/Catechins	(Kochman et al., 2021)
	Caffeine	(Camfield et al., 2014)
	L-theanine	(Baba et al., 2021; Sakurai et al., 2020)
	Caffeine and L-theanine Combo	(Anas Sohail et al., 2021)
	Quercetin	(Khan et al., 2019)
Decreases Aβ Production	EGCG	(Sokary et al., 2022)
	Caffeine	(Arendash et al., 2006; Carman et al., 2014)
Decreases Aβ Accumulation	EGCG	(Sokary et al., 2022)
	Caffeine	(Gardener et al., 2021)
Reduces Neuroinflammation	EGCG	(Kochman et al., 2021)
	Caffeine	(Kochman et al., 2021)
	Rutin	(Xu et al., 2014)
	Quercetin	(Sabarathinam, 2024)
Disaggregates Tau Fibril	EGCG	(Seidler et al., 2022)
	EGCG	(Kochman et al., 2021)
	Caffeine	(Kochman et al., 2021; Prasanthi et

Prevents Oxidative Stress or Oxidative Damage	L-theanine Rutin Quercetin	al., 2010) (Kim et al., 2009) (Xu et al., 2014) (Khan et al., 2019; Sabarathinam, 2024)
Slows Age-related Cognitive Decline	Catechins Quercetin	(Unno et al., 2020) (Nishihira et al., 2021)
Alleviates AD Cognitive Impairment	Catechins L-theanine Rutin	(Haque et al., 2008) (Sakurai et al., 2020) (Javed et al., 2012)
Inhibits Aβ Aggregation	Caffeine Rutin Quercetin	(Ruggiero et al., 2022) (Wang et al., 2012) (Khan et al., 2019)
Decreases Tau Protein Phosphorylation	EGCG Caffeine Rutin Quercetin	(Singh et al., 2016) (Currais et al., 2011) (Shi & Zhao, 2024) (Khan et al., 2019)

As shown in Table 1, catechins, EGCG, caffeine, L-theanine, rutin, and quercetin all possess anti-inflammatory and antioxidant properties. This finding is significant because researchers Kamaljeet et al. (2024) report that antioxidants play a critical role in AD by reducing neuroinflammation, maintaining intracellular oxidative balance, neutralizing free radicals, and protecting against oxidative stress. These factors characterize AD and therefore this finding underscores the importance of components in matcha with antioxidant properties. Similarly, epidemiological studies demonstrate the application of anti-inflammatory drugs to decrease AD incidence. It is important to note, however, that clinical trials with anti-inflammatory drugs have not resulted in success (Ozben & Ozben, 2019). Future research should specifically focus on the anti-inflammatory properties of matcha tea against AD.

Table 1 highlights that EGCG, caffeine, L-theanine, the combination of caffeine and L-theanine, and quercetin promote cognitive function in AD. Fundamentally, it is important to address the collective presence of caffeine and L-theanine in matcha. In addition to their independent effects, the combination of both allows for synergy and increased effectiveness of the tea. The findings highlight that EGCG and caffeine decrease Aβ production and accumulation. Likewise, caffeine, rutin, and quercetin inhibit Aβ aggregation. The literature review details the detrimental impact of Aβ overproduction, accumulation, and aggregation, suggesting that matcha's ability to reduce these prominent AD hallmarks could have significant implications. Table 1 indicates that EGCG, caffeine, rutin, and quercetin

cause a reduction in neuroinflammation. This is significant because Wong-Guerra et al. (2023) note that AD is a neuroinflammatory disease. Therefore, directly preventing AD onset through anti-neuroinflammatory measures demonstrates matcha's functionality in targeting root issues. Moreover, Seidler et al. (2022) suggest that tau fibril disaggregation may be a promising therapeutic approach to AD. Therefore, one of the most prominent findings is EGCG's role in not only inhibiting tau aggregation but actively disaggregating tau fibrils. All the components of matcha tea reviewed in this study prevent oxidative stress or damage. Scientists collectively recognize the role of oxidative stress in AD progression (Chen et al., 2012). Hence, this observation is critical. Furthermore, Table 1 denotes that catechins and quercetin slow age-related cognitive decline. This is notable because AD is the predominant cause of cognitive decline in aged individuals (Murman, 2015). This implies that these two compounds in matcha could act as a therapeutic approach to AD cognitive decline. Catechins, L-theanine, and rutin alleviate AD cognitive impairment. EGCG, caffeine, rutin, and quercetin decrease tau protein phosphorylation. Significantly, researchers Drummond et al. (2020) report that accumulated tau protein phosphorylation is widely regarded as a distinct AD hallmark. Thus, these components mitigate an adverse AD factor.

Overall, Table 1 highlights the specific anti-AD health-promoting properties the components in matcha tea exhibit against several factors that play a prominent role in AD pathology and progression. These compounds do not solely perform one function but work independently and collectively to improve AD health outcomes through numerous mechanisms. This demonstrates matcha tea's ability to prevent AD onset and mitigate AD symptoms.
In addressing the research question, catechins, EGCG, caffeine, L-theanine, the synergistic effect of caffeine and L-theanine, rutin, and quercetin contribute to AD prevention in various ways.

Conclusion

In conclusion, matcha tea has the potential to act as a preventative measure and therapeutic approach against AD. Based on the findings, matcha could contribute to current AD treatment approaches as an additional lifestyle adjustment. Matcha is accessible and possesses anti-AD health-promoting properties that may supplement and amplify current prevention strategies.

As aforementioned, the properties of matcha alleviate symptoms of several other neurological diseases including Parkinson's, Huntington's, and ALS. Thus, further exploration into the potential of matcha to enhance human health against neurodegenerative disorders as a whole may be beneficial to examine. Future studies should clarify which matcha dosage regimen improves both short and long-term AD cognitive functioning the best. Human studies should assess the optimal amount of matcha an individual should consume to maximize the tea's benefits without adverse effects. Additionally, further research is required to determine the specific effects of catechins, caffeine, and L-theanine individually on AD cognitive functioning versus the effects caused as a result of the combination of the three components. Similarly, future research should investigate the ratio of caffeine and L-theanine in matcha necessary to optimize the synergistic effects of both against AD. Based on the existing body of literature, individuals should consider implementing matcha into their daily lifestyle.

Limitations

While this research provides valuable insights, it is limited by the differences in the quality of matcha tea that the studies utilized. For instance, many researchers used commercial matcha tea from Japan which is generally of higher quality and contains the compounds that meet the conditions necessary to produce certain effects such as an improvement in cognitive functioning. These teas, however, differ from those found on international markets. This suggests that studies need to examine the chemical composition of the matcha tea sample before evaluating its effectiveness against various health conditions (Sokary et al., 2022). It is also important to acknowledge that although numerous studies demonstrate an overall improvement in health, the studies use small sample sizes and are heterogeneous which

makes it difficult to draw broad conclusions on them (Sokary et al., 2022). Thus, future studies should aim to create larger, diverse samples in order to accurately determine the effect of matcha on different groups of individuals.

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