Flavonoids: Can They Reduce or Even Prevent Cognitive Decline?

By Job van Benthem (S4778804)
Supervised by: Prof. Dr. Gertjan van Dijk

Abstract

Many studies observed that older people are more likely to experience cognitive decline, in contrast to younger individuals. This decline in cognitive function often entails worsening of memorization, alertness and executive function. The composition of the diet is thought to have a major influence on the health of an older individual and may also have an effect on cognitive function. Additionally, as the diet is suggested to affect cognitive function, polyphenols could be a suitable ingredient for this diet. Polyphenols are bioactive compounds originating from plant-based foods and around the 20th century, the research on these polyphenols began to expand. There are several published studies suggesting that the supplementation of polyphenols results in cognitive improvements. Flavonoids are a subclass of these polyphenols and are found to have beneficial effects on several cognitive functions such as attention, psychomotor speed, memory and executive function. These flavonoids can also be subdivided into different types. Overall, there are several plant-based food products, including exotic fruits, cacao products and berries, found to contain relatively high concentrations of different flavonoid types. Therefore, this essay evaluates the effect on cognitive function after the incorporation of some specific flavonoids and flavonoid-based foods into the diet. Especially the effects of flavonoids found in blueberries, cacao and (citrus) fruits will be evaluated, as recently a lot of research has already been conducted on the flavonoid composition of these food products. This Essay aims to provide an adequate overview of flavonoid consumption and its effect on cognitive functions (such as memory, alertness and executive function) in older adults who are often vulnerable to cognitive decline. Additionally, several key brain mechanisms, such as inflammation and blood flow, that are influenced by age and flavonoid supplementation, are explained as well. Moreover, the feasibility of the consumption of flavonoids will also be taken into account, in order to provide adequate advice for older people associated with cognitive decline or even to prevent reductions in cognitive function.

Introduction

Probably everyone recognizes the effect of cognitive decline during daily life. For example, a grandfather or grandmother who has difficulties remembering things you said the day before. Or even an uncle or your parents who are struggling with a difficult task or reacting to the comments and remarks you have. Moreover, people at an older age are also more afraid of becoming associated with cognitive diseases like dementia (Meyer et al., 2024). Is this fear justified? Yes, unfortunately, this fear is justified. Although not everyone, individuals at an older age are more likely to experience cognitive decline. More specifically, older adults often show reduced ability to form and recall old memories, reduced alertness and weakened executive functioning compared to younger individuals (Lenze et al., 2022). Several studies are ongoing to investigate cognitive diseases such as Alzheimer's disease and dementia (Van Dyck et al., 2023). Therefore, to get a better understanding of the specific cause for cognitive decline, shouldn't we first start by providing an adequate diet for the older individuals among us? A study by Tessier et al., (2025) observed that increased intake of plant-based foods such as fruits, vegetables, whole grains, nuts and legumes resulted in enhanced healthy aging, compared to a diet that includes a lot of trans fats, sodium, sugary beverages and red or processed meats. This healthy aging includes improved mental health and maintained cognitive function. Furthermore, according to another study, American people aged 65 or older tend to eat more nutritious food on average compared to younger individuals. Nevertheless, the dietary quality of the older age group was still below the goal for a healthy diet. Moreover, the cohort group aged 65 years or older was also the only group from which the Healthy Eating Index, which assesses whether food intake aligns with the dietary guidelines, decreased from 1999 to 2016 (Miller et al., 2016). Additionally, statistical analysis revealed that among older individuals, 28% of the men and 21% of the women were affected by malnutrition. Therefore, the diet, and in particular improving the quality of the restricted diet among older individuals, might be a good target for improving or recovering cognitive function in older adults (Yannakoulia et al., 2018).

In relation to the effects of food on healthy ageing, considerable research has been conducted since the end of the 20th century. It is ongoing regarding the biological impact of polyphenols on human health (de Pascual-Teresa et al., 2017). Polyphenols are bioactive compounds found in plant-based foods. The molecules of these bioactive compounds are characterized by at least two phenyl rings, including one or multiple hydroxyl substituents. Polyphenols can be classified into flavonoids or non-flavonoid subgroups. Flavonoid types are based on oxidation state and the pattern of hydroxylation, contributing to different types of flavonoids: flavanals, anthocyanidins, anthocyanins, isoflavones, flavones, flavanols, flavanones and flavanonols. Some of these flavonoids are illustrated in Figure 1. The activity of these polyphenols in the brain depends on their availability in tissues and ability to cross the blood-brain barrier (Grabska et al., 2023). Several studies have already shown that specifically flavonoids induce multiple beneficial effects on human cognitive function (Faysal t al., 2025). Additionally, at a cellular level, some flavonoids can enhance antioxidative defense, inhibit pro-inflammatory cytokine production and promote cell life duration by enhanced repair mechanisms. Other interesting findings

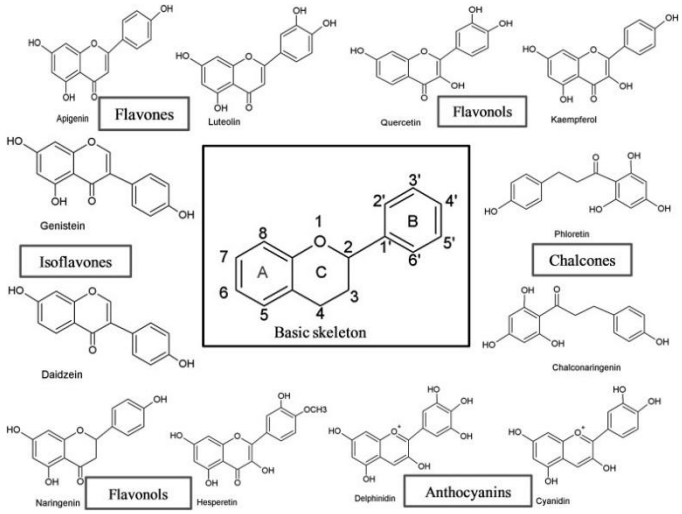

Figure 1: basic molecular skeleton structure of some common flavonoids *and their subclasses.*
(Panche et al., 2016)

include the stimulation of injury healing, reducing lesion size and stimulating synaptic plasticity and neurogenesis (Faysal et al, 2025). Flavonoids can be found in multiple food products. Some examples of foods containing high concentrations of specific flavonoids are wild blueberries, citrus fruits, cacao products and some tea types (Wood et al., 2023)(Saini et al., 2022)(Bloomfield et al., 2023)(Willem et al., 2018). Research by Wood et al., (2023) has already shown that wild blueberry extract, containing relatively high concentrations of anthocyanins(flavonoids), can affect cognitive function upon supplementation. The same holds for several kinds of fruits, which have been found to induce a beneficial effect on memorization (Krikorian et al., 2010). Additionally, a study by Fanelli et al., (2024) suggests that flavonoids can be positively associated with cognitive abilities as well, including executive function. Furthermore, research conducted by McCabe et al., (2010) indicated that there is a strong relation between memory and executive function. This relation is also apparent in neurodegenerative diseases. For instance, cognitive diseases like Alzheimer's are marked by both a decline in memory and executive function (Kirova et al., 2015).

In general, several studies have shown that cognitive function declines with age, including memory and executive functioning. Also, there seems to be a correlation between these cognitive functions. As flavonoids are found to improve cognitive functioning, a current overview of the known effects of specific flavonoids on these cognitive functions would be compelling. Therefore, this Essay aims to provide an overview with examples of the most recent knowledge of foods containing flavonoids and the effects of these specific flavonoids on cognitive functions such as memory, alertness and executive function by supplementation. Overall, this article will mostly focus on older adults, as with age, the probability of cognitive decline increases. In addition to the effect on cognitive functions, the effect of flavonoids on underlying brain processes, such as blood flow and inflammation, will be described as well. Furthermore, it will be evaluated whether or what kind of flavonoids or flavonoid-based food products should be advised to older adults, to maintain or recover their cognitive function.

Effect of 'normal' ageing on brain mechanisms

Cognitive function

Normal ageing is associated with a decline in cognitive functions such as memory, attention, executive functioning, and processing speed. In this case, the term 'normal ageing' describes the ageing of the brain without accompanying neurodegenerative diseases. For instance, individuals suffering from neurodegenerative diseases like dementia are associated with a similar decline in the mentioned cognitive functions with ageing. However, in this case, the decline is associated with a more severe loss of cognitive function, in contrast to normal ageing (An et al., 2018). According to a large-scale study by An et al., (2018), which investigated the effect of ageing on cognitive function in Chinese males and females who were not affected by cognitive disorders, no rapid change in MMSE (Mini-Mental State Examination) score among both males and females until the age of 70 years was found. These results also correlate with a study conducted in the Netherlands. As there is no rapid change observed in cognition before the age of 70, it was suggested that global cognition remains relatively stable during the period before 70 years of age. Although there is often no rapid or strong decline in cognitive function until the age of 70, in general, the ability of the brain to perform complicated cognitive functions still decreases at a slow pace (and sometimes at a fast pace) during life. Some examples of cognitive functions that are generally declining during early adulthood are processing speed, reasoning and memory. Nevertheless, other less complex cognitive functions as vocabulary,

remain at the same level throughout almost your entire life. Despite the decline in complex functions during early adulthood is often not very significant, this decline can already influence an individual's daily activities and quality of life (Corley et al., 2023). Therefore, preventing this decline in cognitive function is essential to reduce the risk of neurodegenerative diseases.

Common characteristics of brain ageing on a cellular level

Additionally, normal brain ageing affects brain mechanisms at the cellular level, as well as ultimate cognitive functions. Along with ageing, molecular and cellular damage will accumulate in the brain and affect its functioning. In general, 12 hallmarks are common in normal ageing, including genomic instability, telomere attrition, epigenetic alterations, loss of proteostasis, defective macroautophagy, deregulated nutrient sensing, mitochondrial dysfunction, cellular senescence, stem cell exhaustion, altered intercellular communication, chronic inflammation, and dysbiosis (Gaspar-Silva et al., 2023). Eventually, neuronal cell degeneration leads to a decline in brain volume. Moreover, the mentioned hallmarks are closely related to inflammation. As an example, cellular senescence induces inflammation and the other way around, ultimately leading to a vicious cycle. Also, disabled macrophage function contributes to immunosenescence due to the increased inability to remove senescent cells from brain tissue (Li et al., 2023).

Protein aggregation

A common example of processes that cause neuronal cell damage during life is protein aggregation, like Tau hyperphosphorylation. In general, tau phosphorylation is useful in supporting microtubules in the brain by binding to these organelles. However, hyperphosphorylation causes the detachment of these tau proteins from microtubules, resulting in loose tau proteins in the environment of the neuronal cell. These loose tau proteins can cluster together and form protein aggregations, which can suppress and choke a neuronal cell in the case of high abundance of protein aggregations. Also, the detachment of these tau proteins from the microtubules leads to reduced or impaired axon functioning and transport of nutrients. Besides, the abundance of tau aggregates can reduce the synaptic connectivity and negatively affect neuronal signaling, which is important for several cognitive functions (Iqbal et al., 2009).

Blood perfusion

Furthermore, alterations in blood perfusion in the brain are also associated with ageing. Blood perfusion entails the delivery of fresh blood to the capillaries in the brain tissue. However, there are several contradicting studies suggesting that, along with ageing, perfusion in some brain regions decreases, while other studies observed an increase in perfusion with age. Therefore, a study by Hu et al., (2025) used for the first time both volumetric (entire brain volume is analyzed, e.g., amount of regional perfusion) and surface-based (analyzing the cortical surface, e.g. amount of gyrification) analyses with the correction of non-partial volume effect(PVE) with ASL-MRI perfusion to investigate the effect of age on brain perfusion. With this method, the change in regional brain perfusion is measured in combination with a possible correction by the ratio between blood flow and tissue abundance (e.g., a decrease in grey matter automatically leads to an increase in relative blood volume for that area). This study found that age causes a decrease in perfusion in the grey matter of the brain and a slight decrease in cerebral blood flow (CBF). However, this decrease in CBF was not significant. Eventually, the most relevant result from this study, even after correcting with PVE, was that the changes in perfusion induced by age are, in general, considered to be regional. This suggests that there is neither an overall increase nor a decrease in brain perfusion with ageing. Overall, there are counteracting studies about the effects of cerebral blood flow and perfusion on cognitive functions. A

small-scale study by Hua et al., (2019) found that, overall, individuals with mild cognitive impairment were associated with increased cerebral blood volume(CBV) compared to controls. This study also indicates that increased CBV might be a marker of long-term effects or region-specific pathology associated with Aβ(Beta amyloid) deposition, which is a biomarker for Alzheimer's disease (Anand et al., 2024). On the other hand, a large-scale study by Leeuwis et al., (2018), including South Asian, European and African Caribbean individuals, found an overall positive relation between cerebral blood flow and the performance on executive function and attention. In contrast to the other nationality groups, the European group also showed a positive relation between cerebral blood flow and memorization. Additionally, large-scale research by Moonen et al., (2021) found similar effects along with increased CBF, including improved cognitive scores in verbal memory, working memory, and psychomotor speed and reduced chances of mild cognitive impairment or dementia. Moreover, the study by Moonen et al., (2021) indicated that low cerebral blood flow is a consistent marker for cognitive decline and cognitive diseases like dementia as well, and lower late-life cerebral blood flow is even strongly associated with increased mortality risk. Ultimately, the contradictory studies on the effect of cerebral blood flow on cognitive function, in combination with the regional changes in blood flow/perfusion with age, could mean that an increase in blood flow/perfusion in some brain areas induces a positive effect, and in additional areas, there might be no effect or even a negative outcome for specific cognitive functions. Therefore, further studies should focus more specifically on flavonoids affecting regional brain perfusion and the eventual cognitive effects.

Several food components that include specific flavonoids

There are various food components containing flavonoids. However, the type and concentrations of flavonoids in these food components vary. One food component that contains high concentrations of flavonoids is wild blueberries. These berries are found to contain specific flavonoids, particularly anthocyanins (Wood et al., 2023). Additionally, tart cherries are also among the foods that contain high concentrations of anthocyanins (Brunetti et al., 2023). Moreover, concord grape fruit contains high concentrations of flavonoids, with almost half of these being anthocyanins. Research found that from these anthocyanins, delphinidin-3-O-glucoside and cyanidin-3-O-glucoside are the major ones. About 10% of the total polyphenol amount found was identified as procyanidins and about 29% of the total polyphenol amount consisted of other polyphenols than flavonoids (Stalmach et al., 2011).

Another food type that contains high concentrations of specific flavonoids is citrus fruit. These fruits typically contain polymethoxylated flavones (PMFs), which are a subgroup of flavonoids, including flavones. These PMFs include nobiletin, tangeritin and 5-demethyl nobiletin (Saini et al., 2022). Nobiletin is also found in citrus fruits such as the ponkan mandarin orange (Hashimoto et al., 2022). And just like Nobiletin, tageritin could also be found in several other citrus fruits (Wani et al., 2024). Moreover, Moro orange, another citrus fruit, is rich in anthocyanins. This type of orange is a cultivar of red orange, meaning it is cultivated and bred by humans(Cardile et al., 2015). Additionally, the original fresh-squeezed orange juice also contains a high concentration of flavanones, including Hesperidin(the major one) and, to a lesser extent, narirutin and didymin (Vanamala et al., 2006).

Furthermore, a different food type than mentioned before, Cacao products, are found to contain high concentrations of cocoa flavanols. The cocoa flavanols come from the Theobroma cacao bean. (Bloomfield et al., 2023; Palma-Morales et al., 2023). The most abundant flavanols found in cocoa are

epicatechin, catechin and procyanidins. Epicatechin is the most abundant flavanol; this flavanol can be rapidly absorbed and can cross the blood-brain barrier very easily (Katz et al., 2011; Baker et al., 2023). In addition to cacao products, tea, wine, apples, pomegranates and berries also contain epicatechin, catechin and procyanidins (Ottaviani et al., 2012). An example of tea containing catechins is matcha green tea drinks(Willem et al., 2018). Matcha is a finely ground green tea from Japan. Unlike other tea types, for the preparation of matcha green tea, the whole leaf is used in powder form.

To summarize, there are many examples of plant-based food products containing high concentrations of specific flavonoids. Blueberries, tart cherries and concord grapes contain high concentrations of anthocyanins. Additionally, citrus fruits such as ponkan mandarin, moro orange, and freshly squeezed orange juice contain flavanones like nobiletin, as well as hesperidin and anthocyanins. Moreover, cocoa products also contain many flavonoids, some of which are also found in foods such as matcha green tea, apples, and wine.

Altered brain mechanisms induced by flavonoids

As the process of normal ageing affects several brain mechanisms at a cellular level, it is also relevant to evaluate the influence of some specific flavonoids on these mechanisms. Therefore, in this section, the supplementary effect of several flavonoids, such as cocoa, anthocyanins and other flavonoids or flavonoid-containing foods in several crucial brain mechanisms will be described. These mechanisms include blood flow, inflammation/oxidative stress and neurotransmission.

Blood flow/perfusion

Research by Bloomfield et al., (2023) found that flavonoid-rich cocoa supplementation could provide a neuroprotective effect in the brain during oxygen deprivation (severe hypoxia). The potential mechanism for this protective effect, suggested by this study, is that cocoa flavanols increase the availability of nitric oxide(NO). NO production is reduced by hypoxia, and epicatechin, a cocoa flavanol, can improve endothelial NO species (NOS) by scavenging NOS and enhancing endothelial function. Although these findings have not been investigated in humans, in theory, epicatechin can cross the blood-brain barrier, act at the endothelial level, and eventually, on neuronal NOS. Furthermore, flavonoid-rich cocoa was also found to enhance cerebral blood volume and tissue oxygenation. Additionally, research by Gratton et al., (2020) showed that cocoa flavanol supplementation resulted in more efficient tissue oxygenation in the frontal areas of the brain during induced hypocapnia (deficient CO_2 concentrations in the blood), which overlaps with the findings from Bloomfield et al., (2023). The improved efficiency in coupling between hypercapnia and vasodilation observed is a consequence of stronger and faster tissue oxygenation. These phenomena indicate acute improvements in cerebrovascular reactivity in the frontal cortex. Moreover, this study suggested that flavanols might increase levels of NO, as shown in peripheral endothelial function, and thereby positively affect cerebrovascular reactivity. However, as mentioned before, increased blood flow or perfusion might not be beneficial for every brain region. Thus, further studies should examine whether increased flow and perfusion benefit the brain and what concentrations of epicatechin could improve cognitive functioning.

In addition to the effects of cocoa flavanols on blood flow, a study by Wood et al., (2023) did not find an effect of blueberry supplementation, containing high concentrations of anthocyanins, on cerebral blood flow or perfusion. This overlaps with a study conducted by Woolf et al., (2023), who did not find a change in NO metabolites with the consumption of blueberries. Nevertheless, the study by Wood et al., (2023) did find an improvement in endothelial function, based on flow-mediated dilation, after blueberry supplementation. On top of that, research by Lamport et al., (2016) found that the consumption of flavonoid-rich citrus fruits enhances blood flow to the brain in healthy young adults, which was observed with cocoa supplementation as well. This result was obtained by measuring an increase in regional perfusion in the inferior and middle right frontal gyrus.

Inflammation and oxidative stress

In addition to the effects of flavonoids on blood flow to and perfusion in the brain, several findings have been reported regarding the effects of flavonoids and flavonoid-containing foods on inflammation and oxidative stress. A study by Nair et al. (2014) involving individuals with metabolic syndrome found that blueberry supplementation resulted in decreased superoxide and total reactive oxygen species. Also, an increased number of myeloid dendritic cells was observed. Further, monocyte gene expression of TNFα, IL-6, TLR4 and serum GMCSF(which supports the production of white blood cells) was reduced. These findings indicate that monocyte expression and whole blood oxidative stress can be reduced by the consumption of blueberries. A study by Thorén et al., (2007) found that myeloid dendritic cells can play a protective role during oxidative stress by neutralizing extracellular oxygen radicals. Additionally, a study by Woolf et al. (2023) also found a reduction in oxidative stress with the supplementation of blueberries. At least partly, the reduction of oxidative stress was related to improved endothelial function. This study also observed an increase in flavonoid metabolites, which indicates the use of these flavonoids in metabolic pathways. Furthermore, research by Rowe et al., (2011) observed that the consumption of Concord grape juice was related to an increase in the number of circulating γδ T cells. The γδ T cells are a subset of T-cells and are associated with both effector and regulatory functions in the immune system. Additionally, other studies found a positive relation between the concentration of brain-derived neurotrophic factor (BDNF) and the daily supplementation with high amounts of cocoa flavanols, in contrast to supplementation with low flavanol amounts. Moreover, the supplementation of Perilla seed oil in combination with Ponkan powder increased BDNF levels as well. BDNFs are negatively correlated with inflammation, as they can reduce the release of inflammatory cytokines, induce neuronal communication and neuronal plasticity (Nehatdoust et al., 2016; Hashimoto et al., 2022).

Protein aggregation

The reason for mentioning the effect of flavonoids or flavonoid-containing foods on inflammatory responses and oxidative stress is that these phenomena are both consequences and causes of neurodegeneration (Zhang et al., 2023). For instance, protein aggregates, which are very common during neurodegeneration, can induce inflammation. On the other hand, chronic inflammation and oxidative stress could also enhance protein aggregation, leading to eventual enhanced inflammation by those protein aggregates. Currently, several studies have indicated that flavonoids could also directly affect the formation of protein aggregates. For example, a study conducted by Li et al., (2017) demonstrated that cyanidin-3-O-glucoside (C3G) and malvidin 3-O-glucoside (M3G), both anthocyanins, could inhibit the hyperphosphorylation of tau proteins in Alzheimer's disease (Boespflug et al., 2018). Additionally, a study by Shengkai et al., (2022) found that supplementation of flavonoids from the stem and leaves of Scutellaria Baicalensis Georgi, a herb plant, led to reduced expression of several tau proteins in rats. This inhibition of tau proteins was associated with

neuroprotection and improvements in memory. Finally, according to a study by Zapletic et al., (2019) quercetin can clear Aβ aggregates and also hamper paralysis via the activation of macroautophagy. Macroautophagy is the process of removing damaged organelles, proteins, or other components from a cell via double-membraned vesicles, which are eventually eliminated with the help of lysosomes. Overall, A large number of signaling pathways and cells originating from the central nervous system are thought to be involved in affecting inflammation. However, many of them are still not well understood. Currently, blocking or inducing inflammatory signaling pathways is thought to be the most promising strategy for treating neurodegenerative diseases. Therefore, flavonoid supplementation might be a potential treatment for preventing this inflammation-induced damage.

Neurotransmission

For the performance of neuronal cell communication, neurotransmitters are essential for delivering 'messages' to other neuronal cells. A study by Duan et al., (2025) showed that the simultaneous consumption of Phosphatidylserine(flavonoid) and a-linolenic acid by 190 mild cognitive impaired(MCI) patients in China led to increased levels of acetylcholine (ACh), GABA and serotonin. Additionally, a study by Orhan et al., (2007) found that quercetin(flavonoid) can inhibit Acetylcholinesterase(AChE) by about 76.2 %. AChE is responsible for the rapid breakdown of ACh in neuronal and muscle cells. ACh is an important neuromodulator, meaning that it is not necessarily an excitatory or inhibitory neurotransmitter. In the brain, ACh can change the excitability of neurons, presynaptic release of other neurotransmitters in the brain, and coordinate the different signal-firing groups of neurons (Picciotto et al., 2012). One of the causes of Alzheimer's disease is a reduced cholinergic transmission to brain regions like the entorhinal cortex, crucial for memory and spatial recognition, and the hippocampus. An induced supply of ACh could partly resolve this problem (Brown et al., 2021). Additionally, according to a study from Meltzer et al., (1998), there is increasing evidence that a combination of disturbances in cholinergic and serotonergic functions could be partly responsible for the cognitive impairment in Alzheimer's disease. Furthermore, according to another study, GABA spinal fluid levels are also significantly reduced in people associated with Alzheimer's disease, and analysis on cortical tissues showed reduced GABA concentrations and reduced activity of the GABA-synthesizing enzyme (Mohr et al., 1986). GABA is crucial for the regulation of neuronal excitability. According to these findings, the supplementation of the flavonoid Phosphatidylserine together with a-linoleic acid could help reduce cognitive impairments in people who are associated with dementia and Alzheimer's disease, and also mild cognitive decline. This also accounts for quercetin, a promising flavonoid for protecting neurotransmission in the brain.

In summary, the consumption of some specific flavonoids can have a beneficial effect on cerebral blood flow and perfusion. These are interesting findings, as reduced blood flow in the brain is a marker for cognitive decline. Nevertheless, excessive blood flow and perfusion need to be prevented, as this could negatively affect cognitive function as well. Moreover, there are also several examples of flavonoids that attenuate or prevent inflammation and oxidative stress by inhibiting the release of inflammatory cytokines and inducing the release of BDNF. Furthermore, several flavonoids have been found to promote the levels of neurotransmitters and prevent the degradation of neurons or neuronal networking, leading to the maintenance of neuronal cell communication.

Flavonoids affecting memory

Blueberries

A study by Wood et al., (2023) involving older individuals, aged 65 to 80 years, demonstrated that wild blueberry extract, containing anthocyanins, enhanced episodic memory processes. The episodic memory can be explained by an individual's personal diary, in which past events, from several years ago to a few days ago, can be described in great detail. In this study, the episodic memory of the older individuals was examined by recalling words from a list during the experiment. Another study by Krikorian et al., (2010) found that supplementation with wild blueberry juice for 12 weeks also improved memory function in older individuals associated with early memory decline. However, the sample size of this study was relatively small. Furthermore, in research that has been done on older adults with mild cognitive impairment, it has been shown that 16 weeks of blueberry supplementation induced Blood-Oxygen-Level-Dependent signal (BOLD)activation in several brain regions. BOLD is used to measure neural activity. This neuronal activity was found in the pre-central gyrus, left-middle frontal gyrus and left inferior parietal lobe during working memory conditions. Nevertheless, there was no obvious correlation between the performance of working memory-related tasks and blueberry consumption (Boespflug et al., 2018). An explanation might be that the effects on the working memory-related tasks would become visible after a longer period of intervention only.

Concord grape

Another example of anthocyanin-containing foods that affect memory is concord grape juice. Research conducted by Krikorian et al., (2010) found that concord grape juice could improve non-verbal learning and they also observed a non-significant enhancement of verbal and spatial recall. This study was performed on 12 older adults with memory decline, however not affected by dementia. Concord grape juice consist high concentrations of polyphenols, and especially flavonoids like anthocyanins (Blumberg et al., 2015). Additionally, a more recent study from Coelho et al., (2021) did not find cognitive improvements in alertness, energy and strength by concord grape juice consumption in adults associated with excessive body weight. There was no correlation between the concentration and absolute amount of total polyphenols, compared to the outcomes of the cognitive tests. Nevertheless, it needs to be indicated that the concentrations of polyphenolic compounds in the other test meals of this study were not investigated. In case these meals were composed of flavonoids as well, this may also be a reason why there are no significant results for cognitive function observed.

Cocoa

Additionally, a study by Akyürek et al., (2024) with younger adults investigated the effect of cocoa flavanols on cognitive function. They did not find an effect of cocoa flavanol supplementation on attention and working memory specifically. Moreover, a similar study with young adults did not show an effect of cocoa flavanols on the visual working memory (Altınok et al., 2022). However, research by Field et al., (2011), examining the acute effects of cocoa flavanol supplementation in young adults, did find an improvement in spatial memory. Nevertheless, a main point of criticism in this research is that the participants knew what type of chocolate (dark or white) they were eating, potentially leading to a placebo effect. On the other hand, in contrast to the research conducted among younger individuals, research with older individuals, who are often associated and vulnerable to cognitive decline, showed a positive effect on verbal fluency tests along with the consumption of cocoa flavanols. Verbal fluency is highly correlated with working- and episodic memory (Mastroiacova et al., 2015). Additionally, another large-scale study with older individuals, performed by Brickman et al., (2023), found a positive correlation between dietary cocoa flavanol consumption and

hippocampal-dependent memory. Therefore, cocoa flavanols may have a stronger observable effect on memory among older individuals.

Various

Further, catechin-rich oil palm leaf extract supplementation, from which catechin is known to be a cocoa flavanol, showed enhancing effects on short-term memory as well. Also, spatial visualization and processing speed were improved. The period of catechin-rich oil palm leaf extract consumption was positively associated with short-term memory, spatial visualization and processing speed (Mohammed et al., 2013). Another example of a catechin-containing product affecting human memory is matcha green tea. Research by Dietz et al., (2017) showed that consumption of matcha green tea slightly improves secondary episodic memory. Moreover, a study by Sakurai et al., (2020) showed that matcha green tea consumption by older women resulted in cognitive improvements as well. The improvements included memory, language, and attention. These findings of beneficial effects on memory also correlate with research that found cognitive improvements in working memory among elderly women (Liu et al., 2018). Nevertheless, among younger women, no effect on cognitive function was found.

Flavonoids affecting alertness

Blueberries

In the previous section, the effects of some specific flavonoids on memory were described. In the next part, the cognitive effects of specific flavonoids on alertness will be explained. A study by Cheng et al., (2024) about wild blueberry extract affecting cognitive function in healthy older adults found a reduction in reaction time of the participants during executive function-related tasks, suggesting an improvement in both executive functioning and possibly alertness as well. Additionally, a study by Barfoot et al., (2019) also found an improvement in alertness, based on reaction time, after blueberry consumption by healthy children. On the other hand, a study by Curtis et al., (2024) found no effect of freeze-dried blueberry powder on alertness and other examined cognitive functions, such as executive function and memory. These results were remarkable as previous studies performed by the same researchers had found significant effects on cognitive functions like alertness. However, the contradictory outcomes of these studies could be explained by the age of the participants. The current study was performed on individuals with an average age of 63 years old. In the other study, where the highest cognitive benefits were observed, the participants were around 75-80 years old. Therefore, these findings indicate that age could be an influencing factor for observing a cognitive effect from the consumption of these blueberries. Furthermore, another study by Watson et al., (2019) examined the acute effect of anthocyanin-rich blackcurrant juice on cognitive function in young healthy adults. It was found that alertness was improved and fatigue was reduced upon the supplementation of the blackcurrant juice.

Cocoa and Matcha tea

Another example of flavonoid-based foods that could affect alertness is matcha green tea. A study by Dietz et al., (2017) found that the consumption of matcha green tea, containing high concentrations of epigallocatechin flavonoids, significantly improves attention and psychomotor speed. On the other hand, research by Karabay et al., (2018) found that the consumption of cocoa flavanols, containing epicatechins as well as matcha green tea, does not affect short-term attention and integration.

However, reaction time was decreased in a visual search task with a medium effect size, and without losing accuracy. This suggests that cocoa flavanol consumption enhances search efficiency. Additionally, another research on healthy young adults examining the acute effects of cocoa flavanols on cognitive control and response inhibition did not find a clear effect. Specifically, the accuracy, frequency of errors and response inhibition were not affected by cocoa flavanol consumption (Altinok et al., 2025). These results overlap with the study from Karabay et al., (2018).

Citrus

Furthermore, research by Alharbi et al., (2016) described, based on previous research, that flavonoid-rich citrus fruits could have a beneficial effect on cognition. Therefore, they conducted a clinical trial with adult males who consumed a flavonoid-rich orange juice (272 mg of flavonoids). They found that the group that consumed flavonoid-rich orange juice were associated with increased attention, compared to the placebo group. Additionally, a later decline in attention within the placebo group was attenuated for the individuals who consumed the orange juice. It needs to be indicated that not every individual experienced a beneficial effect in all cognitive tests. However, the majority of the participants were observed to have an overall improvement in cognitive function. An interesting finding by the study of Alharbi et al., (2016) is that cognitive benefits from flavonoid-rich orange juice can be detected already within 6 hours after consumption.

Flavonoids affecting executive function

Blueberries

In addition to alertness, in this section, the effects of some specific flavonoids on executive function will be described. Executive function is an overall term for high-cognitive functions such as cognitive flexibility, working memory, inhibitory control, planning, reasoning and problem solving (Cristofori et al., 2019). Therefore, the cognitive functions of memory and alertness, as discussed before, overlap with executive functioning and are needed for a sufficient cognitive performance. Moreover, many studies investigating the effect of flavonoids on executive function often include the effect on alertness or attention as well. According to a study by Wood et al., (2023), including older adults who were at risk for cognitive decline, an enhancing effect in executive function was observed upon the consumption of wild blueberry extract. This was observed by the improved results in a switching accuracy test. These findings of cognitive improvements in executive function correlate with the results from a study by Whyte et al., (2017), including children. In this study, a significant decrease in reaction time during a task related to executive functioning was found. The reaction time is seen as a parameter for executive function, but also alertness. Another study found that altered plasma concentrations of anthocyanins, which are found in blueberries, and phenolic acids were correlated with cognitive function. The change (0-90 days) in plasma concentration of one anthocyanin (malvidin-3-O-galactoside) was correlated with the change in switch error on the task-switching test (TST), used to examine the executive function of the individuals. Individuals with greater improvement on the TST had smaller increases in plasma concentrations of malvidin-3-O-galactoside, which could be due to the increased uptake by the cortex tissue (Rutledge et al., 2021). A previous study with rats did show that this type of anthocyanin was most abundant in the cortex. Additionally, a positive relation was found between malvidin-3-0-galactoside concentrations in the cortex and the performance of the Morris water maze experiment (Rutledge et al 2021).

Cocoa

In addition to the effects of anthocyanin-containing foods on executive function, cocoa flavanols are also found to induce an effect related to executive performance. A small-scale study with healthy male adults by Decroix et al., (2016) found no effect of acute cocoa flavanol supplementation on executive function. Additionally, no effects on attention and episodic memory were observed. Nevertheless, according to their findings, this research still suggests that supplementation with cocoa extract could have beneficial effects on executive function/attention for people with poor habitual diet quality. Another study by Tsukamoto et al., (2025) with healthy male adults, in contrast to the other study, found a positive effect in decision making and the inhibitory process of executive function. This inhibitory process is crucial for preventing frequencies of impulsive responses, distractions and automatic responses like emotion. Moreover, a study by Neshatdoust et al., (2016) also observed an improvement in overall executive function after daily supplementation with high amounts of cocoa flavanols, in contrast to supplementation with low amounts of flavanols. On top of that, additional research found improvements in alertness and executive function for healthy older adults after daily cocoa flavanol consumption as well (Garciá-cordero et al., 2021; Vazour et al., 2023).

Various

Finally, the study by Alharbi et al., (2016), mentioned before, demonstrates that the performance of executive tests and psychomotor responses was significantly improved by the consumption of flavonoid-rich orange juice, compared to the placebo group. This correlates with a study by Kean et al., (2015) on healthy older adults, which also observed improvements in executive function. Nevertheless, this improvement was (just not quite) not considered significant. Another study by Lamport et al., (2016) observed that daily consumption of a juice made from concord grape fruit (containing high levels of flavonoids) by healthy mothers also improves executive functioning. An interesting finding by this study was that the washout of flavonoids from the diet for several weeks did not directly result in the loss of improvements in cognitive function. Furthermore, the supplementation of tropical nobiletin-rich ponkan mandarin powder in combination with Perilla seed oil was found to improve executive functioning as well (Hashimoto et al., 2022).

Food products		Major type of flavonoids	Role in brain mechanisms	Effect on cognitive functions
Blueberries		• Anthocyanins	• Increased Flow-mediated dilation • Decreased superoxide and reactive oxygen species • TNFα, IL-6, TLR4 and serum GMCSF expression decreased • Increased amount of myeloid dendritic cells	• Improved overall and episodic memory • Increased alertness • Enhanced executive function
Concord grape juice		• Anthocyanins • Procyanidins	• Increased number of effector and regulatory γδ T cells	• Improved spatial and verbal memory • Enhanced executive function
Citrus fruits	**Citrus fruit in general**	• Polymethoxylated flavones (PMFs), which includes nobiletin, tangeritin and 5-demethyl nobiletin	• Enhanced blood flow to the brain, by increased regional perfusion in the inferior and middle right frontal gyrus. • Positively related with BDNF	
	Ponkan powder with perilla seed oil	• Nobiletin		• Enhanced executive functioning • Increased alertness
	Moro orange	• Anthocyanins		
	Fresh squeezed orange juice	• Hesperidin • Narirutin • Didymin		• Enhanced executive function
Cacao products		• Cocoa flavanols: epicatechin, quercetin, catechin and procyanidins	• Positively related with BDNF • Increased availability of NO • Enhanced cerebral blood volume and oxygenation, especially in frontal cortex • Protects neurotransmission	• Improved overall memory • Enhanced executive function, and also improved regulation of executive function.
Matcha green thee		• Epicatechins	• Epicatechins can cross blood-brain barrier	• Improved alertness • Enhanced executive function

Table 1: several food products, including the major type of flavonoids they contain, and their effect on brain mechanisms and cognitive function. This table provides an overview of food products that contain, in general, high concentrations of specific flavonoids. Also, the type of flavonoids that are included in these products, as well as their role in underlying brain mechanisms and their effect on cognitive function are mentioned. For the brain mechanisms, the effects on blood flow, inflammation and oxidative stress are included. Additionally, the effects of the different flavonoids on cognitive functions entail memory, alertness and executive functioning. An important side note is that the effects found are mostly significant in older adults who are often vulnerable to cognitive decline, and in younger individuals, some of the described effects from the supplementary flavonoid-containing foods were not always experienced.

Expenditure and feasibility of flavonoid supplementation

In the end, the consumption of flavonoids and flavonoid-containing foods needs to be sustainable and affordable as well for every individual who desires improvements in their cognitive functioning. In case a specific flavonoid or flavonoid-containing food product has a protective or recurring effect on cognitive function in older adults, the consumption of this product should be feasible. In the case of anthocyanin-rich blueberries, an individual who desires to improve their cognitive function, the flavonoids needed could just be obtained by consuming the blueberries. Nevertheless, for receiving the required amount of flavonoids to experience cognitive effects, you have to eat two handfuls of blueberries every single day, or at least very regularly. According to several studies, the amount of flavonoids you need every day to experience cognitive benefits from blueberry consumption is about 500 milligrams (mg) per day (Watson et al., 2019). The amount of anthocyanins in a single blueberry is between 85 and 270 mg per 100 gram (Hérnandez et al., 2022). Therefore, an individual needs to consume about 280 grams of blueberries every day in order to receive the beneficial cognitive effects. Although this amount is not impossible to consume every day, for many people, especially the elderly, who tend to eat less, it might not be feasible. Currently, there are already some alternative ways of consumption. For instance, it is also possible to use a powder or extract from these blueberries to obtain the flavonoids, which could be implemented in the diet. Although a powder extract of these blueberries is not very cheap. As an example, based on online web shops, 227 grams of blueberry powder can cost about 17 euros or even more. So, the consumption of this powder regularly is therefore only available to people with sufficient financial means. Besides, while the blueberry powders are often promoted as very natural, the ingredient lists do not always include flavonoids, and it is also not specified elsewhere on many websites whether their products actually contain flavonoids (morgenisnu.nl, 2026; vimergy.eu, 2026). Therefore, for online ordering of products that are promoted to be related to flavonoid-rich foods, it is crucial to always critically assess the information on the seller's website.

In addition to blueberries, cocoa flavanols seem to be more feasible for daily consumption in comparison with blueberries. About 40 grams of unsweetened baking chocolate, which is one of the food components with the highest concentrations of cocoa flavanols, contains around 592 mg of flavanols (Cooperman, 2026). This amount is similar to the 500 mg used in research that found improvements in cognitive function (Baker et al., 2023). The amount of 40 grams of baking chocolate is equivalent to a small chocolate bar, and therefore, daily consumption would be doable. Additionally, the cost of baking chocolate in Dutch supermarkets is about 5 euros per 200 grams (ah.nl, 2026). Therefore, the consumption of baking chocolate for receiving cocoa flavanols could be considered feasible.

Finally, citrus fruits like orange juice could be consumed as well for obtaining the desired flavonoids. According to Gil-Izquierdo et al., (2001), fresh-squeezed orange juice contains around 648.6 mg per liter of flavanones, and according to Alharbi et al., (2016), 272 mg can already improve cognitive skills such as executive functioning. Therefore, daily consumption of about 400 milliliters of fresh orange juice would be sufficient to obtain benefits for cognitive functions. However, this amount of orange juice can still be a lot for someone who doesn't prefer to drink orange juice, and especially for older individuals who eat less. Furthermore, in the Dutch supermarkets, the price for half a liter of fresh-squeezed orange juice is two and a half euros (Ah.nl, 2026). Although these product costs are not a lot, for daily consumption, this product might not be affordable for each individual.

Discussion

To summarize, this Essay described several aspects of flavonoid supplementation, including its effect on the brain and cognitive functioning in humans. According to previous research, individuals at an older age are often more afraid of becoming cognitively impaired and are also at greater risk for cognitive decline, in contrast to younger individuals. It was aimed to provide an adequate overview of common food products containing flavonoids, the effects of these flavonoids on key brain mechanisms altered with age, and also the eventual role of specific flavonoids on cognitive function. In this Essay, cognitive function entailed the cognitive tasks of memorization, alertness, and executive function, and these were evaluated. Additionally, the feasibility of flavonoid consumption was assessed. And eventually, a compact overview of the evaluated food products, the major flavonoids they contain, and examples of their role in brain mechanisms and cognitive function was provided in Table 1.

According to the findings of the literature research, in general, many studies have been conducted on the effect of flavonoid supplementation of blueberries, cacao, and, to a lesser extent, (citrus, grape) fruits. By focusing on blueberries, several studies observed beneficial effects of the consumption of blueberries on cognitive function. These blueberries were found to contain high concentrations of anthocyanins, a subclass of flavonoids. The improvements in cognitive functions included episodic memory and working memory. However, for working memory, no clear improvements were observed in cognitive-related exercises. An explanation for this could be that the timespan of 16 weeks in the related study was too short for detecting significant results. For instance, other studies investigating the protective effects of vitamins or other supplements on cognitive health often last more than 16 weeks, and sometimes even more than 3 years (McGrattan et al., 2018). In addition to blueberries, several studies indicated that cacao products, containing high concentrations of cocoa flavanols, also improved overall memory in humans. Moreover, supplementation with concord grape fruit was found to improve memory as well. On the other hand, the consumption of blueberries, cocoa flavanols and concord grape fruit, as well as the original orange juice, all correlated with improvements in executive function. This was also the case for the consumption of matcha green tea and other citrus fruits. Besides, several studies indicated that especially the consumption of blueberries and matcha green tea improved alertness among individuals. Since alertness is found to be highly correlated with executive functioning, the flavonoid-containing foods affecting executive functioning probably also enhanced alertness (VanVleet et al., 2016). However, this was not clearly observed or targeted during the other related studies.

Overall, many studies evaluated in this essay found significant effects of flavonoid consumption in older individuals, although not always in younger adults. As previously indicated, this could be due to the fact that the neuronal health and communication at a younger age are still sufficient for the brain to perform cognitive tasks. At a later age, little damage or degeneration of neuronal cells could already affect the activity and communication between neurons, leading to features of cognitive decline. According to Edler et al., (2020), individuals at an older age are often associated with increased injury and alterations in neurons, dendritic spines, synapses and neurotransmitters, accompanied by reduced cerebral blood flow, a weakened blood-brain barrier and increased glial cell activation. Eventually, these aspects might cause the induced protective and enhancing effects on the mentioned brain mechanisms by the described flavonoids to be more apparent in older individuals, in contrast to younger adults. This could also be an explanation for the more frequent observed significant effects on cognitive functions observed in older adults, rather than in younger individuals, and especially among those who are vulnerable or associated with cognitive decline.

By evaluating the feasibility of consuming flavonoid-containing foods, it was clear that the way of consumption in itself would probably not be an issue. However, the daily amount of flavonoid-containing food consumption and expenditure could be a point of critique. In the case of blueberries, the consumption of whole blueberries would be too much daily. Moreover, an alternative like a powder extract of blueberries is often way too expensive for daily consumption. Additionally, the consumption of fresh-squeezed orange juice seems to be more ideal for daily consumption, as the costs are much lower in contrast to blueberry extract. Nevertheless, the amount of consumption might still not be ideal for older individuals, because individuals at an older age tend to eat less. Finally, the consumption of cacao products, containing cocoa flavanols, seems to be the most feasible option. The reasoning is that products containing cocoa flavanols are often low in costs and the amount of daily consumption is also reasonable. Still, for older people who eat less and do not prefer the taste or structure of cacao products like dark or baking chocolate, daily consumption will be a challenge. This generally applies to all supplementary foods.

Although there were several promising effects found along with the consumption of flavonoid-based products, there are also some strong limitations. Various studies specifically examined the effect of specific flavonoids, such as anthocyanins, on cognitive function. However, in this Essay, there are also many studies using whole food products containing high concentrations of flavonoids during their research. And often these products also contain other beneficial ingredients for neuronal health and related brain mechanisms, like vitamin C (Guarnieri et al., 2007). Therefore, the effect of flavonoid-containing foods on cognitive function and other mechanisms in the brain, which are also mentioned in Table 1, is not necessarily caused by the flavonoids from these foods only. For that reason, it is sensible to realize that, in addition to flavonoids, many other ingredients from a food product can affect the performance of the brain. Follow-up studies should use the flavonoids only from the food resource and ensure that the other components from the used food products are excluded. Furthermore, according to a bunch of studies, many flavonoids provide a positive effect on cognitive functioning. Nevertheless, there are also examples of flavonoids that are possibly associated with a decline in cognitive performance. For instance, research on the supplementation of high amounts of the flavonoid peonidin found an association with increased risk for mild cognitive impairment (Liu et al., 2024). Thus, generalizing flavonoids and polyphenols as healthy supplements is not quite right.

In conclusion, a lot of research has already been conducted on the effects of flavonoid-containing foods such as blueberries, cacao and, to a lesser extent, citrus fruits and other plant-based products. Many studies observed an improving effect in cognitive functions for all these flavonoid-containing foods, including beneficial effects on memory, alertness and executive functioning. Moreover, there are multiple examples of brain mechanisms, such as neurotransmission, inflammation and blood flow, affected by the supplementation of these flavonoids. Ultimately, cocoa flavanols from cacao products seem to be the most feasible flavonoids for daily consumption for older individuals, which also provide significant benefits for cognitive functions like memory and executive function. Although many flavonoids have a positive effect on neuronal health, there are also flavonoids found to induce a negative effect on cognitive performance, making it very important to always critically examine all the possible effects of these promising flavonoids on human health before creating a flavonoid-based supplementary advice for supporting cognitive functioning.

References

- Ah.nl.(2026). AH Vers geperst sap sinaasappel. https://www.ah.nl/producten/product/wi47354/ah-vers-geperst-sap-sinaasappel
- Ah.nl.(2026). Verkade Kookchocolade 74% cacoa. https://www.ah.nl/producten/product/wi510684/verkade-kookchocolade-74-cacao?utm_source=google&utm_medium=cpc&utm_campaign=NL%2FNL%20-%20AO%20-%20Shopping%20-%20pMax%20-%20NB%20-%20COP%20-%20High%20-%20Robbers%20%26%20Ghosts&gads=EAIaIQobChMIyYmtiYSdkgMVXZKDBx3yzQGxEAQYCCABEgJI3fD_BwE&utm_id=20794709246&gad_source=1&gad_campaignid=20798577259&gbraid=0AAAACxMM_Ute7yOhUab-OW4EH5uNn__3&gclid=EAIaIQobChMIyYmtiYSdkgMVXZKDBx3yzQGxEAQYCCABEgJI3fD_BwE
- Akyürek, E. G., Altınok, A., & Karabay, A. (2024). Concurrent consumption of cocoa flavanols and caffeine does not acutely modulate working memory and attention. *European journal of nutrition*, *64*(1), 35. https://doi.org/10.1007/s00394-024-03514-8
- Alharbi, M. H., Lamport, D. J., Dodd, G. F., Saunders, C., Harkness, L., Butler, L. T., & Spencer, J. P. (2016). Flavonoid-rich orange juice is associated with acute improvements in cognitive function in healthy middle-aged males. *European journal of nutrition*, *55*(6), 2021–2029. https://doi.org/10.1007/s00394-015-1016-9
- Altınok, A., Karabay, A., & Akyürek, E. G. (2022). Acute effects of cocoa flavanols on visual working memory: maintenance and updating. *European journal of nutrition*, *61*(3), 1665–1678. https://doi.org/10.1007/s00394-021-02767-x
- Altinok, A., Moruzzi, M., & Akyürek, E. G. (2025). Acute effects of cocoa flavanols on cognitive control and response inhibition. *Nutrition (Burbank, Los Angeles County, Calif.)*, *139*, 112860. https://doi.org/10.1016/j.nut.2025.112860
- Anand, S., & Schoo, C. (2024). Mild Cognitive Impairment. In *StatPearls*. StatPearls Publishing
- An, Y., Feng, L., Zhang, X., Wang, Y., Wang, Y., Tao, L., Lu, Y., Qin, Z., & Xiao, R. (2018). Patterns of cognitive function in middle-aged and elderly Chinese adults-findings from the EMCOA study. *Alzheimer's research & therapy*, *10*(1), 93. https://doi.org/10.1186/s13195-018-0421-8
- Baker, L. D., Manson, J. E., Rapp, S. R., Sesso, H. D., Gaussoin, S. A., Shumaker, S. A., & Espeland, M. A. (2023). Effects of cocoa extract and a multivitamin on cognitive function: A randomized clinical trial. *Alzheimer's & dementia : the journal of the Alzheimer's Association*, *19*(4), 1308–1319. https://doi.org/10.1002/alz.12767
- Barfoot, K. L., May, G., Lamport, D. J., Ricketts, J., Riddell, P. M., & Williams, C. M. (2019). The effects of acute wild blueberry supplementation on the cognition of 7-10-year-old schoolchildren. *European journal of nutrition*, *58*(7), 2911–2920. https://doi.org/10.1007/s00394-018-1843-6
- Boespflug, E. L., Eliassen, J. C., Dudley, J. A., Shidler, M. D., Kalt, W., Summer, S. S., ... & Krikorian, R. (2018). Enhanced neural activation with blueberry supplementation in mild cognitive impairment. *Nutritional neuroscience*, *21*(4), 297-305.
- Bloomfield, P. M., Fisher, J. P., Shaw, D. M., & Gant, N. (2023). Cocoa flavanols protect cognitive function, cerebral oxygenation, and mental fatigue during severe hypoxia. *Journal of applied physiology (Bethesda, Md. : 1985)*, *135*(2), 475–484. https://doi.org/10.1152/japplphysiol.00219.2023
- Blumberg, J. B., Vita, J. A., & Chen, C. Y. O. (2015). Concord grape juice polyphenols and cardiovascular risk factors: Dose-response relationships. *Nutrients*, *7*(12), 10032-10052.
- Brickman, A. M., Yeung, L. K., Alschuler, D. M., Ottaviani, J. I., Kuhnle, G. G. C., Sloan, R. P., Luttmann-Gibson, H., Copeland, T., Schroeter, H., Sesso, H. D., Manson, J. E., Wall, M., & Small, S. A. (2023). Dietary flavanols restore hippocampal-dependent memory in older adults with lower diet quality and lower habitual flavanol consumption. *Proceedings of the National Academy of Sciences of the United States of America*, *120*(23), e2216932120. https://doi.org/10.1073/pnas.2216932120
- Brown, A. J. H., Bradley, S. J., Marshall, F. H., Brown, G. A., Bennett, K. A., Brown, J., Cansfield, J. E., Cross, D. M., de Graaf, C., Hudson, B. D., Dwomoh, L., Dias, J. M., Errey, J. C., Hurrell, E., Liptrot, J., Mattedi, G., Molloy, C., Nathan, P. J., Okrasa, K., Osborne, G., … Tobin, A. B. (2021). From structure to clinic: Design of a muscarinic M1 receptor agonist with potential to treatment of Alzheimer's disease. *Cell*, *184*(24), 5886–5901.e22. https://doi.org/10.1016/j.cell.2021.11.001
- Brunetti, L., Wang, L., Wassef, A., Gong, Y., Brinker, A., Buckley, B., Lipsky, P. E., Ondar, P., Poiani, G., Zhao, L., Kong, A. N., & Schlesinger, N. (2023). Pharmacokinetics and Pharmacodynamics of Anthocyanins after Administration of Tart Cherry Juice to Individuals with Gout. *Molecular nutrition & food research*, *67*(9), e2200550. https://doi.org/10.1002/mnfr.202200550
- Cardile, V., Graziano, A. C., & Venditti, A. (2015). Clinical evaluation of Moro (Citrus sinensis (L.) Osbeck) orange juice supplementation for the weight management. *Natural product research*, *29*(23), 2256–2260. https://doi.org/10.1080/14786419.2014.1000897

- Cheng, N., Barfoot, K. L., Le Cozannet, R., Fança-Berthon, P., Lamport, D. J., & Williams, C. M. (2024). Wild Blueberry Extract Intervention in Healthy Older Adults: A Multi-Study, Randomised, Controlled Investigation of Acute Cognitive and Cardiovascular Effects. *Nutrients*, *16*(8), 1180. https://doi.org/10.3390/nu16081180
- Coelho, O. G. L., Alfenas, R. C. G., Debelo, H., Wightman, J. D., Ferruzzi, M. G., & Mattes, R. D. (2021). Effects of Concord grape juice flavor intensity and phenolic compound content on glycemia, appetite and cognitive function in adults with excess body weight: a randomized double-blind crossover trial. *Food & function*, *12*(22), 11469–11481. https://doi.org/10.1039/d1fo02049h
- Cooperman, T. (2026). How much dark chocolate equals a tablespoon cocoa powder?. ConsumerLab.com. https://www.consumerlab.com/answers/how-much-dark-chocolate-equals-a-tablespoon-of-cocoa-powder/dark-chocolate-cocoa-flavanols/#:~:text=Answer:,is%20not%20a%20reliable%20indicator.
- Corley, J., Conte, F., Harris, S. E., Taylor, A. M., Redmond, P., Russ, T. C., ... & Cox, S. R. (2023). Predictors of longitudinal cognitive ageing from age 70 to 82 including APOE e4 status, early-life and lifestyle factors: the Lothian Birth Cohort 1936. *Molecular Psychiatry*, *28*(3), 1256-1271.
- Cristofori, I., Cohen-Zimerman, S., & Grafman, J. (2019). Executive functions. *Handbook Of Clinical Neurology*, *163*, 197–219. https://doi.org/10.1016/b978-0-12-804281-6.00011-2
- Curtis, P. J., van der Velpen, V., Berends, L., Jennings, A., Haag, L., Minihane, A. M., Chandra, P., Kay, C. D., Rimm, E. B., & Cassidy, A. (2024). Chronic and postprandial effect of blueberries on cognitive function, alertness, and mood in participants with metabolic syndrome - results from a six-month, double-blind, randomized controlled trial. *The American journal of clinical nutrition*, *119*(3), 658–668. https://doi.org/10.1016/j.ajcnut.2023.12.006
- Decroix, L., Tonoli, C., Soares, D. D., Tagougui, S., Heyman, E., & Meeusen, R. (2016). Acute cocoa flavanol improves cerebral oxygenation without enhancing executive function at rest or after exercise. *Applied physiology, nutrition, and metabolism = Physiologie appliquee, nutrition et metabolisme*, *41*(12), 1225–1232. https://doi.org/10.1139/apnm-2016-0245
- de Pascual-Teresa, S., & Clifford, M. N. (2017). Advances in polyphenol research: A journal of agricultural and food chemistry virtual issue. *Journal of Agricultural and Food Chemistry*, *65*(37), 8093-8095.
- Dietz, C., Dekker, M., & Piqueras-Fiszman, B. (2017). An intervention study on the effect of matcha tea, in drink and snack bar formats, on mood and cognitive performance. *Food research international (Ottawa, Ont.)*, *99*(Pt 1), 72–83. https://doi.org/10.1016/j.foodres.2017.05.002
- Duan, H., Xu, N., Yang, T., Wang, M., Zhang, C., Zhao, J., Li, Z., Chen, Y., Yan, J., Zhang, M., Li, W., Yue, Z., Ma, F., He, R., & Huang, G. (2025). Effects of a food supplement containing phosphatidylserine on cognitive function in Chinese older adults with mild cognitive impairment: A randomized double-blind, placebo-controlled trial. *Journal of affective disorders*, *369*, 35–42. https://doi.org/10.1016/j.jad.2024.09.131
- Edler, M. K., Munger, E. L., Meindl, R. S., Hopkins, W. D., Ely, J. J., Erwin, J. M., ... & Raghanti, M. A. (2020). Neuron loss associated with age but not Alzheimer's disease pathology in the chimpanzee brain. *Philosophical Transactions of the Royal Society B*, *375*(1811), 20190619.
- Fanelli Kuczmarski, M., Crawford, S. B., Sebastian, R. S., Beydoun, M. A., Goldman, J. D., Moshfegh, A. J., Evans, M. K., & Zonderman, A. B. (2024). Association between Flavonoid Intake and Cognitive Executive Function among African American and White Adults in the Healthy Aging in Neighborhoods of Diversity across the Life Span (HANDLS) Study. *Nutrients*, *16*(9), 1360. https://doi.org/10.3390/nu16091360
- Faysal, M., Al Amin, M., Zehravi, M., Sweilam, S. H., Arjun, U. V. N. V., Gupta, J. K., Shanmugarajan, T. S., Prakash, S. S., Dayalan, G., Kasimedu, S., Madhuri, Y. B., Reddy, K. T. K., Rab, S. O., Al Fahaid, A. A. F., & Emran, T. B. (2025). Therapeutic potential of flavonoids in neuroprotection: brain and spinal cord injury focus. *Naunyn-Schmiedeberg's archives of pharmacology*, *398*(7), 8215–8240. https://doi.org/10.1007/s00210-025-03888-4
- Field, D. T., Williams, C. M., & Butler, L. T. (2011). Consumption of cocoa flavanols results in an acute improvement in visual and cognitive functions. *Physiology & behavior*, *103*(3-4), 255–260. https://doi.org/10.1016/j.physbeh.2011.02.013
- García-Cordero, J., Pino, A., Cuevas, C., Puertas-Martín, V., San Román, R., & de Pascual-Teresa, S. (2021). Neurocognitive Effects of Cocoa and Red-Berries Consumption in Healthy Adults. *Nutrients*, *14*(1), 1. https://doi.org/10.3390/nu14010001
- Gaspar-Silva, F., Trigo, D., & Magalhaes, J. (2023). Ageing in the brain: mechanisms and rejuvenating strategies. *Cellular and molecular life sciences : CMLS*, *80*(7), 190. https://doi.org/10.1007/s00018-023-04832-6
- Gil-Izquierdo, A., Gil, M. I., Ferreres, F., & Tomás-Barberán, F. A. (2001). In vitro availability of flavonoids and other phenolics in orange juice. *Journal of agricultural and food chemistry*, *49*(2), 1035–1041. https://doi.org/10.1021/jf0000528

- Grabska-Kobyłecka, I., Szpakowski, P., Król, A., Książek-Winiarek, D., Kobyłecki, A., Głąbiński, A., & Nowak, D. (2023). Polyphenols and Their Impact on the Prevention of Neurodegenerative Diseases and Development. *Nutrients*, *15*(15), 3454. https://doi.org/10.3390/nu15153454
- Gratton, G., Weaver, S. R., Burley, C. V., Low, K. A., Maclin, E. L., Johns, P. W., ... & Rendeiro, C. (2020). Dietary flavanols improve cerebral cortical oxygenation and cognition in healthy adults. *Scientific reports*, *10*(1), 19409. https://doi.org/10.1038/s41598-020-76160-9
- Guarnieri, S., Riso, P., & Porrini, M. (2007). Orange juice vs vitamin C: effect on hydrogen peroxide-induced DNA damage in mononuclear blood cells. *The British journal of nutrition*, *97*(4), 639–643. https://doi.org/10.1017/S0007114507657948
- Hashimoto, M., Matsuzaki, K., Maruyama, K., Hossain, S., Sumiyoshi, E., Wakatsuki, H., Kato, S., Ohno, M., Tanabe, Y., Kuroda, Y., Yamaguchi, S., Kajima, K., Ohizumi, Y., & Shido, O. (2022). *Perilla* seed oil in combination with nobiletin-rich ponkan powder enhances cognitive function in healthy elderly Japanese individuals: a possible supplement for brain health in the elderly. *Food & function*, *13*(5), 2768–2781. https://doi.org/10.1039/d1fo03508h
- Hernández-Carrión, M., & Narvaez, S. C. (2022). Evaluation of antioxidant activity, phenolic content, anthocyanins, and flavonoids of fresh and dried 'Biloxi' blueberries. *Revista Vitae*, *29*(3). https://doi.org/10.17533/udea.vitae.v29n3a348980
- Hua, J., Lee, S., Blair, N. I. S., Wyss, M., van Bergen, J. M. G., Schreiner, S. J., Kagerer, S. M., Leh, S. E., Gietl, A. F., Treyer, V., Buck, A., Nitsch, R. M., Pruessmann, K. P., Lu, H., Van Zijl, P. C. M., Albert, M., Hock, C., & Unschuld, P. G. (2019). Increased cerebral blood volume in small arterial vessels is a correlate of amyloid-β-related cognitive decline. *Neurobiology of aging*, *76*, 181–193. https://doi.org/10.1016/j.neurobiolaging.2019.01.001
- Hu, J., Craig, M. S., Knight, S. P., De Looze, C., Meaney, J. F., Kenny, R. A., Chen, X., & Chappell, M. A. (2025). Regional changes in cerebral perfusion with age when accounting for changes in gray-matter volume. *Magnetic resonance in medicine*, *93*(4), 1807–1820. https://doi.org/10.1002/mrm.30376
- Iqbal, K., Liu, F., Gong, C. X., Alonso, A.delC., & Grundke-Iqbal, I. (2009). Mechanisms of tau-induced neurodegeneration. *Acta neuropathologica*, *118*(1), 53–69. https://doi.org/10.1007/s00401-009-0486-3
- Karabay, A., Saija, J. D., Field, D. T., & Akyürek, E. G. (2018). The acute effects of cocoa flavanols on temporal and spatial attention. *Psychopharmacology*, *235*(5), 1497–1511. https://doi.org/10.1007/s00213-018-4861-4
- Katz, D. L., Doughty, K., & Ali, A. (2011). Cocoa and chocolate in human health and disease. *Antioxidants & redox signaling*, *15*(10), 2779–2811. https://doi.org/10.1089/ars.2010.3697
- Kean, R. J., Lamport, D. J., Dodd, G. F., Freeman, J. E., Williams, C. M., Ellis, J. A., Butler, L. T., & Spencer, J. P. (2015). Chronic consumption of flavanone-rich orange juice is associated with cognitive benefits: an 8-wk, randomized, double-blind, placebo-controlled trial in healthy older adults. *The American journal of clinical nutrition*, *101*(3), 506–514. https://doi.org/10.3945/ajcn.114.088518
- Kirova, A. M., Bays, R. B., & Lagalwar, S. (2015). Working memory and executive function decline across normal aging, mild cognitive impairment, and Alzheimer's disease. *BioMed research international*, *2015*, 748212. https://doi.org/10.1155/2015/748212
- Krikorian, R., Shidler, M. D., Nash, T. A., Kalt, W., Vinqvist-Tymchuk, M. R., Shukitt-Hale, B., & Joseph, J. A. (2010). Blueberry supplementation improves memory in older adults. *Journal of agricultural and food chemistry*, *58*(7), 3996–4000. https://doi.org/10.1021/jf9029332
- Lamport, D. J., Pal, D., Macready, A. L., Barbosa-Boucas, S., Fletcher, J. M., Williams, C. M., Spencer, J. P., & Butler, L. T. (2016). The effects of flavanone-rich citrus juice on cognitive function and cerebral blood flow: an acute, randomised, placebo-controlled cross-over trial in healthy, young adults. *The British journal of nutrition*, *116*(12), 2160–2168. https://doi.org/10.1017/S000711451600430X
- Leeuwis, A. E., Smith, L. A., Melbourne, A., Hughes, A. D., Richards, M., Prins, N. D., Sokolska, M., Atkinson, D., Tillin, T., Jäger, H. R., Chaturvedi, N., van der Flier, W. M., & Barkhof, F. (2018). Cerebral Blood Flow and Cognitive Functioning in a Community-Based, Multi-Ethnic Cohort: The SABRE Study. *Frontiers in aging neuroscience*, *10*, 279. https://doi.org/10.3389/fnagi.2018.00279
- Lenze, E. J., Voegtle, M., Miller, J. P., Ances, B. M., Balota, D. A., Barch, D., Depp, C. A., Diniz, B. S., Eyler, L. T., Foster, E. R., Gettinger, T. R., Head, D., Hershey, T., Klein, S., Nichols, J. F., Nicol, G. E., Nishino, T., Patterson, B. W., Rodebaugh, T. L., Schweiger, J., … Wetherell, J. L. (2022). Effects of Mindfulness Training and Exercise on Cognitive Function in Older Adults: A Randomized Clinical Trial. JAMA, 328(22), 2218–2229. https://doi.org/10.1001/jama.2022.21680
- Li, D., Wang, P., Luo, Y., Zhao, M., & Chen, F. (2017). Health benefits of anthocyanins and molecular mechanisms: Update from recent decade. *Critical reviews in food science and nutrition*, *57*(8), 1729-1741.

- Liu, Q., Zhang, R., Chen, Y., Lu, Y., Cui, F., Zhang, Q., & Zhang, C. (2024). Dietary Flavonoid Intake and Risk of Mild Cognitive Impairment in the Elderly: A Case-Control Study. *Nutrition and metabolic insights*, *17*, 11786388241283779. https://doi.org/10.1177/11786388241283779
- Liu, Y., Fly, A. D., Wang, Z., & Klaunig, J. E. (2018). The Effects of Green Tea Extract on Working Memory in Healthy Women. *The journal of nutrition, health & aging*, *22*(3), 446–450. https://doi.org/10.1007/s12603-017-0962-8
- Li, X., Li, C., Zhang, W., Wang, Y., Qian, P., & Huang, H. (2023). Inflammation and aging: signaling pathways and intervention therapies. *Signal transduction and targeted therapy*, *8*(1), 239.
- McCabe, D. P., Roediger, H. L., McDaniel, M. A., Balota, D. A., & Hambrick, D. Z. (2010). The relationship between working memory capacity and executive functioning: evidence for a common executive attention construct. *Neuropsychology*, *24*(2), 222–243. https://doi.org/10.1037/a0017619
- McGrattan, A. M., McEvoy, C. T., McGuinness, B., McKinley, M. C., & Woodside, J. V. (2018). Effect of dietary interventions in mild cognitive impairment: a systematic review. *The British journal of nutrition*, *120*(12), 1388–1405. https://doi.org/10.1017/S0007114518002945
- Meltzer, C. C., Smith, G., DeKosky, S. T., Pollock, B. G., Mathis, C. A., Moore, R. Y., ... & Reynolds, C. F. (1998). Serotonin in aging, late-life depression, and Alzheimer's disease: the emerging role of functional imaging. *Neuropsychopharmacology*, *18*(6), 407-430.
- Meyer, J. L., Buczak-Stec, E., König, H. H., & Hajek, A. (2024). Fear of Dementia among Middle-Aged and Older Adults in Germany. *Dementia and geriatric cognitive disorders extra*, *14*(1), 96–105. https://doi.org/10.1159/000541066
- Miller, A., & Steinle, N. (2020). Barriers to healthy eating in the elderly; a national and global perspective. *J Hum Nutr Food Sci*, *8*, 1130.
- Morgenisnu.nl.(2026) Wild blueberry powder(Bio).https://morgenisnu.nl/products/wild-blueberry-powder-bio/?gad_source=1&gad_campaignid=21864215905&gbraid=0AAAADo9pBgR7M8brXMukC7Vb7zp4q2_X&gclid=EAIaIQobChMI-7S1qvOckgMVO4CDBx2iuBQ3EAQYASABEgIZevD_BwE
- Mohamed, S., Lee Ming, T., & Jaffri, J. M. (2013). Cognitive enhancement and neuroprotection by catechin-rich oil palm leaf extract supplement. *Journal of the science of food and agriculture*, *93*(4), 819–827. https://doi.org/10.1002/jsfa.5802
- Moonen, J. E., Sabayan, B., Sigurdsson, S., van Buchem, M. A., Gudnason, V., Meirelles, O., & Launer, L. J. (2021). Contributions of cerebral blood flow to associations between blood pressure levels and cognition: the age, gene/environment susceptibility-Reykjavik study. *Hypertension*, *77*(6), 2075-2083.
- Mohr, E., Bruno, G., Foster, N., Gillespie, M., Cox, C., Hare, T. A., Tamminga, C., Fedio, P., & Chase, T. N. (1986). GABA-agonist therapy for Alzheimer's disease. *Clinical neuropharmacology*, *9*(3), 257–263. https://doi.org/10.1097/00002826-198606000-00004
- Nair, A. R., Mariappan, N., Stull, A. J., & Francis, J. (2017). Blueberry supplementation attenuates oxidative stress within monocytes and modulates immune cell levels in adults with metabolic syndrome: a randomized, double-blind, placebo-controlled trial. *Food & function*, *8*(11), 4118–4128. https://doi.org/10.1039/c7fo00815e
- Neshatdoust, S., Saunders, C., Castle, S. M., Vauzour, D., Williams, C., Butler, L., ... & Spencer, J. P. (2016). High-flavonoid intake induces cognitive improvements linked to changes in serum brain-derived neurotrophic factor: Two randomised, controlled trials. *Nutrition and healthy aging*, *4*(1), 81-93.
- Ottaviani, J. I., Kwik-Uribe, C., Keen, C. L., & Schroeter, H. (2012). Intake of dietary procyanidins does not contribute to the pool of circulating flavanols in humans. *The American journal of clinical nutrition*, *95*(4), 851–858. https://doi.org/10.3945/ajcn.111.028340
- Orhan, I., Kartal, M., Tosun, F., & Sener, B. (2007). Screening of various phenolic acids and flavonoid derivatives for their anticholinesterase potential. *Zeitschrift fur Naturforschung. C, Journal of biosciences*, *62*(11-12), 829–832. https://doi.org/10.1515/znc-2007-11-1210
- Palma-Morales, M., Melgar-Locatelli, S., Castilla-Ortega, E., & Rodríguez-Pérez, C. (2023). How Healthy Is It to Fortify Cocoa-Based Products with Cocoa Flavanols? A Comprehensive Review. *Antioxidants (Basel, Switzerland)*, *12*(7), 1376. https://doi.org/10.3390/antiox12071376
- Panche, A. N., Diwan, A. D., & Chandra, S. R. (2016). Flavonoids: an overview. *Journal of nutritional science*, *5*, e47. https://doi.org/10.1017/jns.2016.41
- Picciotto, M. R., Higley, M. J., & Mineur, Y. S. (2012). Acetylcholine as a neuromodulator: cholinergic signaling shapes nervous system function and behavior. *Neuron*, *76*(1), 116–129. https://doi.org/10.1016/j.neuron.2012.08.036
- Rowe, C. A., Nantz, M. P., Nieves, C., Jr, West, R. L., & Percival, S. S. (2011). Regular consumption of concord grape juice benefits human immunity. Journal of medicinal food, 14(1-2), 69–78. https://doi.org/10.1089/jmf.2010.0055

- Rutledge, G. A., Sandhu, A. K., Miller, M. G., Edirisinghe, I., Burton-Freeman, B. B., & Shukitt-Hale, B. (2021). Blueberry phenolics are associated with cognitive enhancement in supplemented healthy older adults. *Food & function*, *12*(1), 107–118. https://doi.org/10.1039/d0fo02125c
- Saini, R. K., Ranjit, A., Sharma, K., Prasad, P., Shang, X., Gowda, K. G. M., & Keum, Y. S. (2022). Bioactive Compounds of Citrus Fruits: A Review of Composition and Health Benefits of Carotenoids, Flavonoids, Limonoids, and Terpenes. *Antioxidants (Basel, Switzerland)*, *11*(2), 239. https://doi.org/10.3390/antiox11020239
- Sakurai, K., Shen, C., Ezaki, Y., Inamura, N., Fukushima, Y., Masuoka, N., & Hisatsune, T. (2020). Effects of Matcha Green Tea Powder on Cognitive Functions of Community-Dwelling Elderly Individuals. *Nutrients*, *12*(12), 3639. https://doi.org/10.3390/nu12123639
- Shengkai, D., & Yazhen, S. (2022). Flavonoids from Stems and Leaves of *Scutellaria baicalensis Georgi* Regulate the Brain Tau Hyperphosphorylation at Multiple Sites Induced by Composited Aβ in Rats. *CNS & neurological disorders drug targets*, *21*(4), 367–374. https://doi.org/10.2174/1871527320666210827112609
- Stalmach, A., Edwards, C. A., Wightman, J. D., & Crozier, A. (2011). Identification of (poly)phenolic compounds in concord grape juice and their metabolites in human plasma and urine after juice consumption. *Journal of agricultural and food chemistry*, *59*(17), 9512–9522. https://doi.org/10.1021/jf2015039
- Tessier, A. J., Wang, F., Korat, A. A., Eliassen, A. H., Chavarro, J., Grodstein, F., ... & Guasch-Ferré, M. (2025). Optimal dietary patterns for healthy aging. *Nature medicine*.
- Thorén, F. B., Betten, A., Romero, A. I., & Hellstrand, K. (2007). Cutting edge: antioxidative properties of myeloid dendritic cells: protection of T cells and NK cells from oxygen radical-induced inactivation and apoptosis. *The Journal of Immunology*, *179*(1), 21-25.
- Tsukamoto, H., Yoneya, S., Koyama, T., Suzuki, A., Yuuki, I. W., Dora, K., & Hashimoto, T. (2025). A single intake of flavanol-rich cocoa improves inhibitory executive process under cognitive fatigue during aerobic exercise in men: a randomized, double-blind, placebo-controlled crossover trial. *Psychopharmacology*, *242*(12), 2713–2724. https://doi.org/10.1007/s00213-025-06826-7
- Vanamala, J., Reddivari, L., Yoo, K. S., Pike, L. M., & Patil, B. S. (2006). Variation in the content of bioactive flavonoids in different brands of orange and grapefruit juices. *Journal of Food Composition and Analysis*, *19*(2-3), 157-166.
- van Dyck, C. H., Swanson, C. J., Aisen, P., Bateman, R. J., Chen, C., Gee, M., Kanekiyo, M., Li, D., Reyderman, L., Cohen, S., Froelich, L., Katayama, S., Sabbagh, M., Vellas, B., Watson, D., Dhadda, S., Irizarry, M., Kramer, L. D., & Iwatsubo, T. (2023). Lecanemab in Early Alzheimer's Disease. *The New England journal of medicine*, *388*(1), 9–21. https://doi.org/10.1056/NEJMoa2212948
- Van Vleet, T. M., DeGutis, J. M., Merzenich, M. M., Simpson, G. V., Zomet, A., & Dabit, S. (2016). Targeting alertness to improve cognition in older adults: A preliminary report of benefits in executive function and skill acquisition. *Cortex; a journal devoted to the study of the nervous system and behavior*, *82*, 100–118. https://doi.org/10.1016/j.cortex.2016.05.015
- Vauzour, D., Scholey, A., White, D. J., Cohen, N. J., Cassidy, A., Gillings, R., Irvine, M. A., Kay, C. D., Kim, M., King, R., Legido-Quigley, C., Potter, J. F., Schwarb, H., & Minihane, A. M. (2023). A combined DHA-rich fish oil and cocoa flavanols intervention does not improve cognition or brain structure in older adults with memory complaints: results from the CANN randomized, controlled parallel-design study. *The American journal of clinical nutrition*, *118*(2), 369–381. https://doi.org/10.1016/j.ajcnut.2023.06.008
- Vimergy.eu. (2026). USDA WILD BLUEBERRY POWDER. https://vimergy.eu/products/wild-blueberry?variant=48656509403382&utm_source=google&utm_medium=organic&utm_campaign=Vimergy%20EU%20English&utm_content=USDA%20Organic%20Wild%20Blueberry%20Powder&gad_source=1&gad_campaignid=23174508713&gbraid=0AAAADMnksY9JbeE0SsW4z_dp66Ej8AvY&gclid=EAIaIQobChMI-7S1qvOckgMVO4CDBx2iuBQ3EAQYAiABEgJ7sPD_BwE
- Wani, I., Koppula, S., Balda, A., Thekkekkara, D., Jamadagni, A., Walse, P., Manjula, S. N., & Kopalli, S. R. (2024). An Update on the Potential of Tangeretin in the Management of Neuroinflammation-Mediated Neurodegenerative Disorders. Life (Basel, Switzerland), 14(4), 504. https://doi.org/10.3390/life14040504
- Watson, A. W., Okello, E. J., Brooker, H. J., Lester, S., McDougall, G. J., & Wesnes, K. A. (2019). The impact of blackcurrant juice on attention, mood and brain wave spectral activity in young healthy volunteers. *Nutritional neuroscience*, *22*(8), 596–606. https://doi.org/10.1080/1028415X.2017.1420539
- Whyte, A. R., Schafer, G., & Williams, C. M. (2017). The effect of cognitive demand on performance of an executive function task following wild blueberry supplementation in 7 to 10 years old children. *Food & function*, *8*(11), 4129–4138. https://doi.org/10.1039/c7fo00832e
- Willems, M. E. T., Şahin, M. A., & Cook, M. D. (2018). Matcha Green Tea Drinks Enhance Fat Oxidation During Brisk Walking in Females. *International journal of sport nutrition and exercise metabolism*, *28*(5), 536–541. https://doi.org/10.1123/ijsnem.2017-0237

- Wood, E., Hein, S., Mesnage, R., Fernandes, F., Abhayaratne, N., Xu, Y., Zhang, Z., Bell, L., Williams, C., & Rodriguez-Mateos, A. (2023). Wild blueberry (poly)phenols can improve vascular function and cognitive performance in healthy older individuals: a double-blind randomized controlled trial. *The American journal of clinical nutrition*, *117*(6), 1306–1319. https://doi.org/10.1016/j.ajcnut.2023.03.017
- Woolf, E. K., Terwoord, J. D., Litwin, N. S., Vazquez, A. R., Lee, S. Y., Ghanem, N., Michell, K. A., Smith, B. T., Grabos, L. E., Ketelhut, N. B., Bachman, N. P., Smith, M. E., Le Sayec, M., Rao, S., Gentile, C. L., Weir, T. L., Rodriguez-Mateos, A., Seals, D. R., Dinenno, F. A., & Johnson, S. A. (2023). Daily blueberry consumption for 12 weeks improves endothelial function in postmenopausal women with above-normal blood pressure through reductions in oxidative stress: a randomized controlled trial. *Food & function*, *14*(6), 2621–2641. https://doi.org/10.1039/d3fo00157a
- Yannakoulia, M., Mamalaki, E., Anastasiou, C. A., Mourtzi, N., Lambrinoudaki, I., & Scarmeas, N. (2018). Eating habits and behaviors of older people: Where are we now and where should we go?. *Maturitas*, *114*, 14-21.
- Zaplatic, E., Bule, M., Shah, S. Z. A., Uddin, M. S., & Niaz, K. (2019). Molecular mechanisms underlying protective role of quercetin in attenuating Alzheimer's disease. *Life sciences*, *224*, 109–119. https://doi.org/10.1016/j.lfs.2019.03.055
- Zhang, W., Xiao, D., Mao, Q., & Xia, H. (2023). Role of neuroinflammation in neurodegeneration development. *Signal transduction and targeted therapy*, *8*(1), 267. https://doi.org/10.1038/s41392-023-01486-5

* Use of artificial intelligence (AI):
AI was used for improving text by the removal of grammatical errors.