UFT Academic Publishing House, Plovdiv

Food Science and Applied Biotechnology
e-ISSN: 2603-3380

Journal home page: www.ijfsab.com
https://doi.org/10.30721/fsab2023.v6.i1

OPEN ACCESS

Review Article

Impact of unconventional Ω-3 sources on cognitive development: A nexus to explore for future brains

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Abstract

A diet opulent in unsaturated fatty acids can influence children's brain health. The purpose of the current review was to evaluate the effect of Ω-3 rich food on children's cognition and brain development. The incidence of dementia in Pakistan and the world is escalating. Therefore, it is necessary to improve children's brain development. For a long time, it has been known that the comparative quantity of certain dietary nutrients is required for cognition and emotional functions in humans. It has been described that the stimulus of nutritional factors on synaptic plasticity and neuronal function has discovered a few of the key mechanisms which are accountable for the act of nutrients on mental function and health. Different gut hormones produced in the brain or that can move into the brain affect cognitive performance. Brain-derived neurotrophic factor acts as metabolic modulators and influences food intake in human. Flax seed, chia seed, and walnut are rich in polyunsaturated fatty acids, which directly impact brain development and cognition. Diet influences cognition, due to which manipulation in diet can improve memory and enhance the neurons' resistance against memory loss.

Keywords

cognition, brain development, synaptic plasticity, flax seed, chia seed, walnut

Abbreviations

BDNF – brain-derived neurotrophic factor; CRE – cyclic AMP-responsive element; GLP1 – glucagonlike peptide 1; IGF1 – insulin-like growth factor 1–OS – oxidative stress; ROS – reactive oxygen species; SDG – secoisolariciresinol diglucoside; SIRT1 - silent information regulator T1; uMtCK - ubiquitous mitochondrial creatine kinase; UCP2 – uncoupling protein 2

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Article history:
Received 24 September 2022
Reviewed 11 February 2023
Accepted 23 February 2023
Available on-line 17 March 2023

https://doi.org/10.30721/fsab2023.v6.i1.232

Introduction

The development of an infant's brain tends to occur at the early stage of human life. Until two years, 75% of brain development completes, and 95% occurs up to 6 years of age (Lenroot and Giedd 2012). In adults, 20% of total energy is consumed by the brain; in children, it takes almost 50% of the metabolic rate (Kuzawa et al. 2014). The vulnerable early years of growth affected by malnutrition decreased the number of brain cells and myelin production and altered neurotransmitters' functioning, leading to cognitive impairments, learning disorders, and schizophrenia. The lack of nutrient supply to white matter injures it and activates microglia, free radical attack, and excitotoxin (Keunen et al. 2015).

The potential of food to defend and prevent illnesses is now being acknowledged, despite its old observation as a source of energy and meeting the body's growing needs. Over the past half-decade, research has unearthed intriguing findings about the effect of dietary variables on critical biochemical systems and processes that keep the brain functioning. A diet rich in Ω-3 fatty acids, for example, is being lauded for its ability to enhance cognitive functions in newborns and upregulate genes involved in synaptic function and plasticity (Steyn 2018). As a result, high-saturated-fat diets are gaining a reputation for decreasing molecular substratum that enables cognitive dispensation and raising the possible factor of neural flaws in people and animals.

Food and other features of everyday living, including physical activity, have played a key part in molding cognitive magnitude and mental development for hundreds of years. Thanks to advancements in molecular biology, food-derived impulses have been shown to influence the metabolism of energy and synaptic plasticity and therefore modulate the impact of diet on cognitive performance, which is believed to have been important for the development of the contemporary brain (Monteleone et al. 2018).

The fact that eating is a fundamental human habit underscores the potential of nutritional intake to control an individual's and community's mental well-being (Rippe 2018). Paleontological data indicates that food availability and brain size are linked and that even small dietary changes may have major consequences for survival and reproductive success. Cooking abilities, food availability, energy conservation, and upright running and walking are all linked with larger brains in humanoids; all these characteristics necessitate cooperation with cognitive methods balanced on effective feeding (Garcia et al. 2021).

The well-studied connections between brain development and food are dietary consumption of Ω-3 fatty acids. The most prevalent Ω-3 fatty acid in brain cell membranes is docosahexaenoic acid (DHA); nevertheless, the body is ineffective at manufacturing DHA, and thus we rely heavily on dietary DHA (Nasir and Bloch 2019). It's been suggested that having an approach to DHA had a major impact on human development in terms of increasing the brain-to-body-mass ratio (encephalization). The fact that DHA is a key brain component backs up the theory that a DHA-rich shore-based diet was required for hominid encephalization. According to archaeological data, early hominids who adapted to eating flax seeds and nuts acquired access to DHA before significant encephalization (Bazinet et al. 2020). The brain's interaction with its surroundings is continuous. Linoleic acid (Ω-6 fatty acid), saturated and trans fatty acids have all risen significantly in Western cultures during the last 100 years, whereas Ω-3 fatty acid consumption has declined (Zarate et al. 2017).

Energy Metabolism and Cognition

The brain requires a huge quantity of energy in comparison to other parts of the body. As a result, the processes that govern the transmission of energy from meals to neurons are anticipated to show an important part in the instruction of brain activity (Navarro 2020). Mechanisms related to energy management in neurons may influence synaptic plasticity, which may explain how metabolic ailments can impair cognition. Synaptic activity, interestingly, may affect metabolic energy, enabling mental activities to impact physical function at the molecular level (Elce et al. 2020). Brain-derived neurotrophic factor (BDNF), a signaling molecule, is an example of a chemical closely connected to synaptic plasticity and energy metabolism: it may activate metabolic signals to influence cognitive performance. The hippocampus and hypothalamus, which are involved with cognitive and metabolic control, have the highest levels of BDNF (Tan and Norhaizan 2019).

In the hippocampus (brain part), learning a task promotes BDNF-mediated synaptic plasticity, while removing the BDNF gene causes cognitive impairment (Kowiański et al., 2018). The Met form of the Val66Met BDNF polymorphism has been related to impaired hippocampal memory processing and functioning in humans and is connected to irregular BDNF trafficking and secretion in neuronal cells (Shen et al. 2018). BDNF, in turn, has been found to affect various energy metabolism characteristics, including insulin sensitivity, appetite suppression, and lipid and glucose metabolism. Furthermore, the energy balance-regulating hypothalamic melanocortin 4 receptor regulates BDNF expression in the ventral medial hypothalamus suggesting a connection between synaptic plasticity and energy metabolism (Zhou 2018).

After a reduced metabolism of energy caused by incorporating a high quantity of vitamin D3 in the brain, the impact of physical activity on downregulating the effects of synaptic plasticity associated with BDNF like cyclic AMP-responsive element (CRE)-binding protein, synapsin I and calcium-dependent protein kinase II were shown to be abolished in rodents (Sabbir 2018). In the human model, a de novo mutation in the BDNF receptor called TrkB has related to hyperphagia and learning and memory problems. Although BDNF-mediated synaptic plasticity and energy metabolism seem to be linked, more research is needed to establish this connection's limits in cognitive function regulation (Krishna et al. 2017).

Nutrients and Cognition

Several dietary constituents have been exposed to influence cognitive skills. Multiple brain functions may be influenced by dietary nutrients which regulate synaptic transmission, neurotransmitter pathways, signal-transduction pathways, and membrane fluidity (Bayrami et al. 2020). Recent findings showed that nutrients could alter synaptic plasticity-related brain circuits (Anfal et al. 2020).

Nutritional lipids, previously believed to influence understanding through cardiovascular physiology, are now being recognized for their effects on the brain. Ω-3 fatty acids are necessary for proper brain function and are found naturally in cell membranes (Wojdasiewicz et al. 2020). Despite the wide range of experimental designs used to assess the impact of various dietary components on cognitive skills, there is widespread agreement that a lack of Ω -3 fatty acids in babies leads to poorer memory and learning ability in adults. A lack of Ω-3 fatty acids in babies' diets has been linked to an amplified threat of different brain-associated disorders, such as dyslexia, attention deficit hyperactivity disorder, schizophrenia, dementia, bipolar disorder, and depression (di Porzio 2020).

We rely on dietary DHA because the DHA consider a key constituent of neuronal membranes, and the body of a human is poor at producing it. Several processes through which DHA influences brain development and cognition are beginning to emerge. Dietary treatment with DHA has been shown to enhance hippocampus BDNF levels and recover cognitive performance in rat models of brain damage (Hashimoto et al. 2017). DHA may improve cognitive skills by increasing synaptic membrane fluidity or enabling synaptic plasticity; it may also operate via its metabolic effects since DHA boosts glucose consumption and mitochondrial function, lowering oxidative stress (OS). DHA is a critical element of brain cells and retinal cells, and it aids in the development of the embryonic brain as well as the prevention of lifestyle illnesses, including atherosclerosis, Alzheimer's disease, and dementia (Mohanty et al. 2017).

Most human research has been attentive to determining the benefits of Ω-3 fatty acids in decreasing the cognitive deficits linked with mental illnesses. Many additional well-publicized studies have attempted to evaluate the impact of Ω-3 fatty acid supplementation on schoolchildren's performance. A randomized, double-blind controlled study is being performed in Durham, UK, with half of the youngsters receiving Ω-3 and the other half receiving placebos (Agostoni et al. 2017). Children were chosen for the new research based on the reason for lower performance at school and were given frequent exams to assess their coordination, attention, and intellectual aptitude. According to early findings, the group receiving Ω-3 showed a modest increase in school performance, prompting a flurry of media conjecture (Ciappolino et al. 2019).

Although the Durham study's findings require further research, they appear to be consistent with those of another study in which 386 children (6 – 12 y old) in Australia and 384 children in Indo-China were given a drink mix containing **Ω**-3 fatty acids like DHA 87mg/day and EPA 23mg/ day and micronutrients (folate, zinc, iron, and vitamins B6, A, C and B12, and). After 5 and 10 months, girls and boys in Australia scored better on tests measuring verbal intelligence, learning, and memory, whereas only girls in Indonesia scored higher. However, findings correlate with earlier research on the function of **Ω**-3 fatty acids in brain growth and cognition. It suggests that some food components may have cumulative effects (Provensi et al. 2019).

In contrast to the health benefits of **Ω**-3 fatty acid-rich diets, epidemiological research shows that diets heavy in trans and saturated fats negatively impact cognition. After just 3 weeks of dietary therapy, rodent research that examined the impact of "junk food," defined by elevated saturated fat and sugar content, showed a decrease in cognition and lower hippocampus levels of BDNF-related synaptic plasticity (Yu et al. 2020). These results indicate that nutrition had an impact on neurons, irrespective of the resistance of insulin or fat. Even more worrisome is that this diet enhanced the neurological load linked to experimental brain injury, as shown by poor learning performance and a reduction in BDNF-mediated synaptic plasticity (Fig. 1). Based on findings that antioxidants and α-tocopherol exacerbated the impacts of the nutrition, elevated OS may facilitate the impact of the nutrition on plasticity (Langley 2017).

Flax seeds, chia seeds, and walnuts are good sources of linolenic and α–linolenic acids, which are converted to arachidonic, DHA, and EPA; they are important for amendable inflammatory responses, optimum growth, immune system function, eye side, brain development, and motor systems for newborn (Martin et al. 2016).

The neural functions of the fetus are greatly affected by the mother's nutritional status. Kids' psychomotor and mental functions are affected by the vitamin D status of the body. In newborns, the fine motor functions are not affected, but the gross motor functions are affected by the body iron status of the mother (Veena et al. 2016). Since low levels of iron are linked to the pathophysiology and complications of ADHD, it plays an important role in managing dopaminergic action. Iron deficiency affects young children's motor, cognitive, emotional functions, and social. Reduced iron level in the brain has been linked to abnormalities in cortical fiber diffusion, modifications in the dopaminergic and serotonergic systems, and myelin-forming (Sree et al. 2020).

The fermentation of fiber in the colon results in butyrate production, adding beneficial effects to the brain; in Parkinson's disease, sodium butyrate helped improve toxicity-induced learning and memory and improved plasticity and regeneration of brain cells (Bourassa et al. 2016). The anti-inflammatory effect of butyrate's G-protein receptors was observed and was present in the brain's microglia. The threat of brain-related diseases can be minimized by introducing butyrate-rich foods like a high-fiber diet (Bourassa et al. 2016).

In brain development, methionine synthase, a cobalamin and Vitamin B9-based enzyme, plays a significant role. A decrease of up to 10-fold of methyl cobalamin was seen in older adults and the fetal brain as well a high value of inactive cyanocobalamin was observed. In autistic and schizophrenic persons, the activity of methionine synthase was decreased due to low levels of MeCbl and AdoCbl, which further resulted in the elevation of homocysteine. The free radical formation was increased, leading to neuropsychiatric problems due to low vitamin B12 (Zhang et al. 2016).

GABA is the main repressive neurotransmitter in the living organism's cortex. The upsurge in brain GABA may be due to a rise in nitric oxide induced by L-arginine, which can disturb blood-brain barrier absorptivity. The impact of GABA-rich food supplementation on mental and cognition can be mediated completely through the blood-brain barrier or partially through the enteric nervous system. The increased GABA can cause flushing, depressed mood, drowsiness in the morning, electric shock sensation to the whole body, malaise, and nausea (Boonstra et al. 2016).

Flavonols are a kind of flavonoid present in seeds, fruits, nuts, beans, and other foods (Gonzalez-Sarrias et al. 2020). Although flavonols' antioxidant properties are well known in vitro, there is a widespread contract that their activities in vivo are more complicated and need additional study. In cerebral ischemic rats, the flavonol quercetin, found in nuts and many seeds, has been shown to improve memory and learning (Kim and Park 2018). In mice, dietary treatment with epicatechin, a plant-derived flavanol that has proven to pass the blood-brain barrier, enhanced angiogenesis, synaptic spine density, and hippocampus-dependent memory. In this research, the beneficial impact of epicatechin-rich food supplementation on memory formation was shown to be increased even more by concurrent exercise (Haskell-Ramsay et al. 2018).

Folate, also known as folic acid, is present in various foods, including chia seeds, flax seeds, and walnuts (USDA 2018). When the gut absorbs vitamin B, the liver produces various folates. The deficiency of folate, which is most often caused by a lack of folate in the diet, has been linked to various physiological problems throughout development (Desai et al. 2016).

Folate insufficiency may lead to neurological problems, including depression and cognitive impairment, if you don't get enough of it. Supplementation of folate, either alone or in combination with B vitamins, has been proven to help prevent cognitive decline and dementia as people age and enhance the benefits of antidepressants (McNulty et al. 2019).

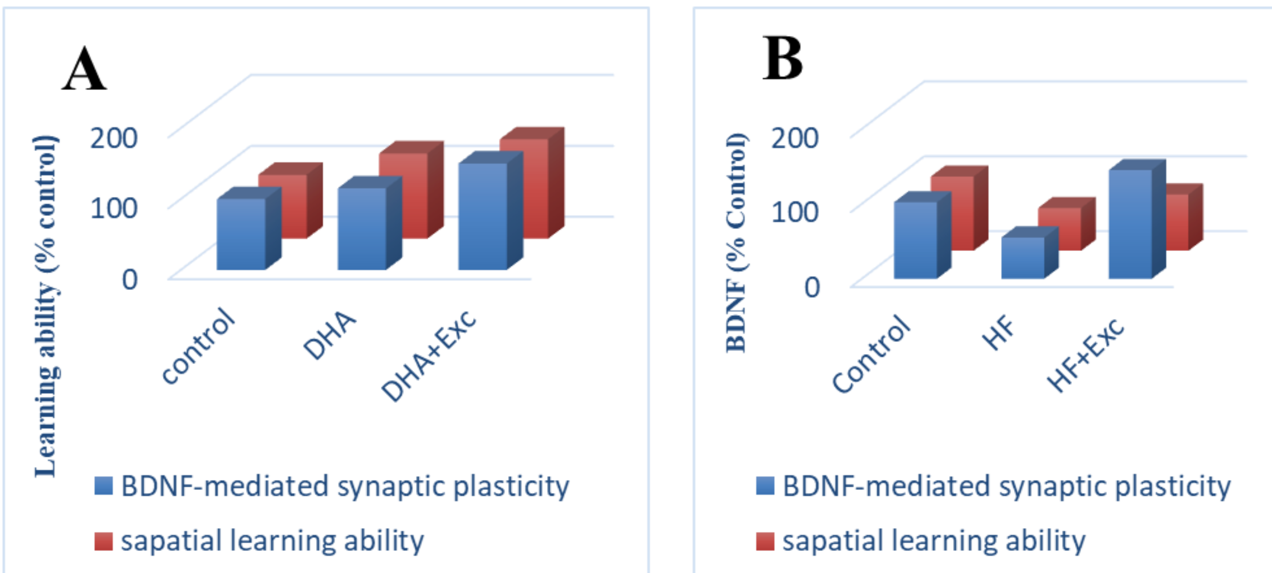

Figure 1. Impacts of feeding and exercise on learning ability and synaptic plasticity

According to the findings of a recent randomized clinical study, folic acid intake for three years may assist in preventing age-related deterioration in cognitive performance. Experts argue that cobalamin status, age, family history, pre-existing medical problems, and the medication regimen of patients taking folate are all significant variables to consider when minimizing undesirable side effects, including cancer, poor immune function, and anemia (Pelletier 2018). Table. 1 explain the role of different nutrients on cognition.

Since babies eat such small quantities compared to their high requirements, enrichment of basic/major food groups will not fix micronutrient deficiencies in babies and young children. During this sensitive point, one strategy for meeting infant nutritional needs is battered enrichment or the manufacture of weaning foods enriched with vitamins and minerals and with an appropriate nutrient composition (Uvere and Ene-ibong 2013). Vitamin and mineral deficiencies and nutritional properties of infant diets in growing countries are identified to deliver background information for developing a suitable macro-and micronutrient composition for enriched/fortified weaning foods (Dewey 2013).

Caloric Intake and Cognition

Changing the caloric amount of one's diet may impact cognitive ability. According to a new study, metabolic processes triggered by burning fuels in mitochondria may regulate some elements of neural plasticity, potentially affecting cognitive performance (Cavaliere et al. 2019). Certain cell metabolism-regulating processes are linked to synaptic function-modulating pathways. Excess calories, for example, may decrease synaptic plasticity and make cells more vulnerable to harm by generating free radical production that exceeds the cell's buffering capacity. Moderate calorie restriction may preserve the brain by decreasing oxidative damage to cellular nucleic acids, lipids, and proteins (Cenini et al. 2019). According to studies, increased OS reduces cognitive performance and BDNF-mediated synaptic plasticity in rats. Calorie restriction also raises BDNF levels, indicating that BDNF may mediate the neuronal plasticity benefits of reduced caloric consumption (Mattson et al. 2003). From weaning to 3 years of age, reducing calorie consumption to around 35% of nominal control levels reduces the cognitive and motor function impairments linked with aging in mice (Mikaelsson 2010).

The "thrifty gene" theory explains that our genetics has evolved over millions of years to profit from little energy to manage inadequate food sources (Tuchman 2020). The effect of meal frequency or calorie intake on health and energy metabolism in humans has long been a topic of study. The fluctuations in meal quantity without a decrease in calorie consumption result in intact levels of many metabolic markers, including leptin, insulin, glucose, and BDNF (Xie et al., 2020). Another research found that keeping participants on an alternate-day caloric-limited diet for two months caused weight reduction and better diabetes and cardiovascular disorder risk profiles. The seeming disparity between these two kinds of research indicates that calorie intake is a key component in physiological consequences suggesting that regulated intermittent caloric restriction and meal skipping may have health advantages in people (Dorling et al. 2020). However, more preclinical data is needed to develop therapeutic applications; therefore, care should be used when interpreting these findings to prevent misunderstandings like the assumption that a low-calorie diet is enough to improve health. This point ignores the reality that a nutritionally balanced diet is necessary for low-calorie diets to provide health advantages. It would be fascinating to see how these dietary changes impact other physiological markers, including hormone profiles and immune system states, which are critical for evaluating the therapeutic advantages of calorie restriction (Weyh et al. 2020).

Antioxidant Foods

The brain is especially vulnerable to oxidative damage due to its elevated metabolic load and plenty of oxidizable material, including the polyunsaturated fatty acids that make up neural cell plasma membranes (Hofer and Perry 2016). Several "antioxidant diets" have gained popularity due to their well-publicized beneficial benefits on brain function. Chia seed, for example, has high antioxidant activity, but only a few of its numerous constitute have been studied separately: two tannins (prodelphinidin and procyanidin), phenolics, and anthocyanins (de Falco et al. 2021). Polyphenols were found to improve hippocampus plasticity (as assessed by increases in IGF1 and HSP70), protect against kainate-induced damage, and improve memory and learning function in rats. It's unclear whether berry extracts improve cognition and synaptic plasticity, but their benefits are most likely linked to their capacity to uphold metabolic homeostasis, which would defend membranes from peroxidation of lipids and influence synaptic plasticity (Ullah et al. 2019).

Micronutrients with antioxidant capability linked to mitochondrial activity have been demonstrated to impact cognitive performance. α-lipoic acid, which may originate in meats like the liver, heart, and kidney, and vegetables like flax seed, broccoli, and spinach, is a coenzyme that helps mitochondria maintain energy balance (Das et al. 2016). α -lipoic acid was found to improve memory impairments in Alzheimer's disease in animal models and to slow cognitive weakening in a limited model of Alzheimer's patients (Boccardi et al. 2016). Vitamin E was found to link to poor memory performance in children, with lower blood concentration of tocopherol being linked to reduced memory performance. Tocopherol, which may be found in various foods such as nuts, vegetable oils, wheat brans, green leafy vegetables, and seeds, has been proven to help aged mice live longer and enhance neurological performance and mitochondrial function (John et al. 2020). The processes through which vitamin E affects cognition are unknown, although they are believed to be linked to antioxidants' potential ability to promote synaptic plasticity by preventing the oxidation of synaptic membranes (Tian et al. 2016).

The effects of food on emotions and cognition may begin even before the act of eating since the emotional state of the brain changes as a result of visual and olfactory sensory inputs (Berthoud et al. 2017). Food consumption causes the secretion of peptides or hormones into the blood, such as glucagon-like peptide 1 (GLP1) and insulin, which subsequently go to the hypothalamus and hippocampus, where they stimulate signal transduction pathways that increase synaptic activity and aid memory and learning (Lin and Hsu 2018). These substances then reach the hippocampus and hypothalamus, activating signal transduction pathways that help synaptic activity and contribute to memory and learning (Bettio et al. 2017). In turn, an empty stomach signals a lack of food, which may trigger the production of ghrelin, which can help neural plasticity and cognitive performance. Chemical signals generated from adipose tissue through leptin may affect learning and memory by activating particular receptors in the hypothalamus and hippocampus (Liu et al. 2019).

Energy Homeostasis and Cognition

Mitochondrial energy generation is essential for sustaining neuronal excitability and synaptic function, which may be affected by diet and exercise (Raefsky and Mattson 2017). The effects of various diets and exercises on synaptic plasticity and cognitive performance may be cumulative. The ATP produced by mitochondria may activate insulin-like growth factor 1 (IGF1) and BDNF, enhancing synaptic plasticity and cognitive performance (Park and Kwak 2017). Energy-balancing molecules, including uncoupling protein 2 (UCP2), AMP-activated protein kinase (AMPK), and ubiquitous mitochondrial creatine kinase (uMtCK) interact with BDNF to control cognition and synaptic development (Fig. 2). Reactive oxygen species (ROS) are formed when too much energy is produced as a consequence of a high caloric intake or intense activity (Madlala et al. 2016). When ROS levels surpass the cell's buffering capacity, signal-transduction modulators like BDNF become less active, impairing cognitive and synaptic plasticity function.

Silent information regulator T1 (SIRT1), a histone deacetylase that helps decrease ROS and helps chromatin modifications that underlie epigenetic alterations that may impair cognition, may be influenced by energy metabolism (Bettio et al. 2017).

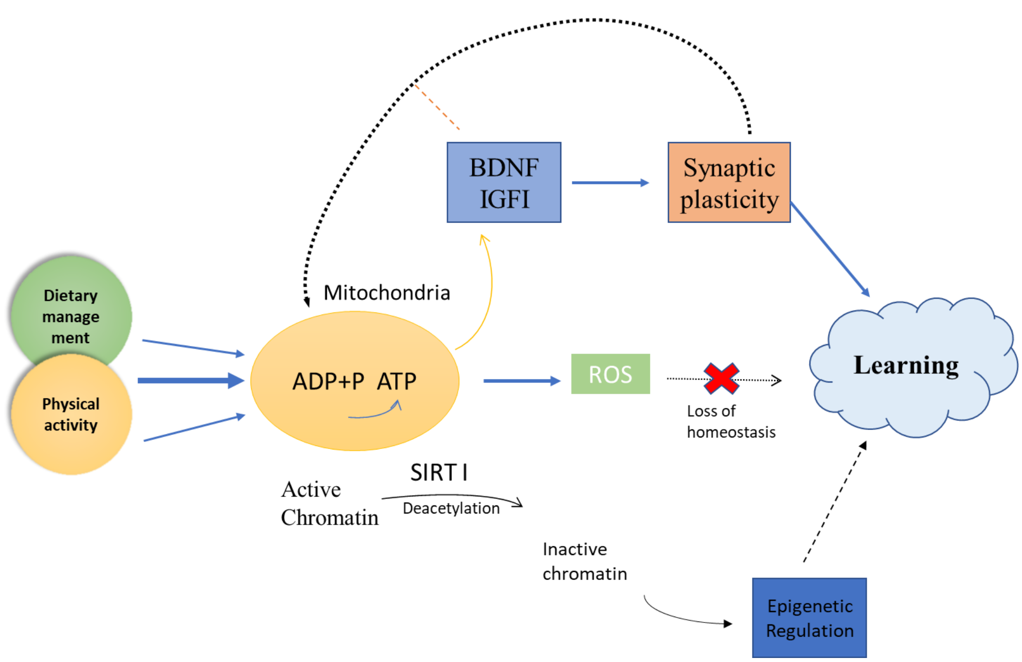

Figure 2. Effects of energy homeostasis on brain development and cognition

Another possible mark for the impact of food is the BDNF gene on epigenetics, which is susceptible to epigenetic alteration. Two key results support the theory that exercise, like nutrition, improves cognitive functions by influencing synaptic plasticity and energy metabolism (Duman et al. 2016). To begin with, combining physical activity and diet increases the expression of UCP2, AMPK, and uMtCK, which may influence energy balance and brain plasticity. Secondly, interrupting energy homeostasis during voluntary wheel-running removed the benefits of physical activity on the activities of BDNF and BDNF end products, which are vital for memory and learning, indicating that energy metabolism affects BDNF function (Muller et al. 2020).

Flax Seeds and Brain Development

Flaxseed is primarily classified as an oilseed crop, according to research. Furthermore, other nutritional characteristics, such as oil content, make it a better option for nutritionists when developing functional meals for growing youngsters (Tufail et al. 2020). Flaxseed is high in ALA, a Ω-3 fatty acid, as well as dietary fiber, protein, and lignan, particularly Secoisolariciresinol diglucoside (SDG) (Parikh et al. 2018).

Table 1. Effect of different nutrients on cognition and brain development

Nutrient	Impacts on cognition and emotion	Food sources
Docosahexaenoic acid	Improvement in function in the elderly; helps in treating mood disorders in patients; improves the cognition in rodents with traumatic brain injury	flax seeds, Fish (salmon) krill, chia, walnuts, kiwi fruit, butternuts,
Flavonoids	Play a role in cognition with physical activity in rodents; improve cognitive ability in the elderly	The ginkgo tree, Cocoa, citrus fruits, green tea, wine, chia seeds
B vitamins	Supplementation with vitamin B12, folate, and vitamin B6 has a beneficial impact on women's memory performance of different ages; vitamin B12 showed improved cognitive damage in rats when fed with a diet deficient in choline	Walnuts, Various natural sources.
Vitamin D	Older adults preserve the cognition	Fatty fish, Fish liver, fortified products, mushrooms, milk, soy milk sunlight
Vitamins (E, C, carotene)	Delays cognition in the elderly when different antioxidant vitamin statuses remain normal	Vitamin C: citrus fruits, Vegetables and plants Vitamin E: seeds and walnut, wheat bran
Calcium, zinc, selenium meat, fish, eggs	Intake of zinc rich diet improves cognition and reduces cognitive decay; High serum calcium is connected with cognitive decline; low selenium level is linked with reduced cognitive function	Calcium: coral, milk Zinc: oysters, beans, walnut, flax seeds, whole grains; Selenium: cereals, nuts.
Copper	Improved copper plasma concentrations are linked with better cognitive performance in Alzheimer's disease	Molasses, oysters, blackstrap, lamb/beef liver, Walnut, black pepper, chia seeds.
Iron	Treatment with iron normalizes cognitive performance in young women	Fish, walnut, red meat, chia seed, poultry

Different studies have shown that flax seed components are beneficial to human nutrition. ALA aids in the growth of a child's brain moreover the reduction of blood lipids and cardiovascular disease. Flax has a high lipid, dietary fiber, and protein content. A study of Canadian brown flax found that it had 40% fat, 19% protein, 29% total dietary fiber, 7.6% moisture, and 3.5% ash. Flaxseed content varies depending on the growing environment, genetics, seed processing, and analytical technique (Bhushana and Pradesh 2020). Flaxseed is an ALA source of Ω-3 and Ω-6 fatty acids, two types of Ω fats (Saini and Keum 2018).

Humans need polyunsaturated fatty acids because the body requires them. In comparison to the Soxhlet extraction technique (56.7%), supercritical CO_2 extraction yielded a higher average ALA content (60.5%) (Deacon et al. 2017).

Chia Seeds as a Source of Ω-3

Chia seeds (*Salvia hispanica L.*) are authorized as a "novel food" by the European Union (EU). Approximately 60 percent ALA and 20 percent Ω-6 linoleic acid are found in the seeds, which contain about 25–40 percent oil. The body needs fatty acids to remain healthy, and can't be made synthetically. Proteins (16–26%), lipids (31–34%), carbs (25–40%), fiber (17–29%), ash (4.5–5.3%), vitamins, minerals, and a high percentage of antioxidants make up chia seeds exceptional (Miranda-Ramos et al. 2020).

Table 2. The effect of seeds and walnut on cognition and brain development

Study design	Result	References
Supplementation of walnut (400mg/kg/d) in cadmium administered to rats for 28 d	• Improved memory impairment through antioxidant and cholinergic activities	(Batool et al. 2017)
Supplementation of walnut in animal and human experiments	• Improved motor function and cognition	(Pribis et al. 2012)
Supplementation of walnut peptides in Tg2576 transgenic mice	• Improved the learning ability and memory in Tg2576 transgenic mice • Improved Aβ25-35 induced memory and learning impairment	(Muthaiyah et al. 2014; Zou et al., 2016)
Study participants were divided into 2 groups: the control group and the intervention group, and given chia seeds (5g daily) to the intervention group for 21 d	• The intervention group significantly performed better than the control group. The intervention group performed well in problem-solving and verbal intelligence	(Onneken 2018)
Consumption of chia, flax seed, and walnut provide Ω-3 (DHA, EPA, ALA)	• EPA and DHA significantly play a role in the development of the brain. Involved in the synthesis of neurotransmitters and their functioning • DHA is crucial for retina maturation and function, and the visual cortex • Supplementation of flax seed in pregnant women causes the better mental processing score in infants • Ω-3 from seed improved cognitive functions and lowered the risk of dementia	(Wlassoff 2018)
Consumption of walnut in rats to improve the scopolamine induces	• Improved memory and learning abilities through increasing sensitivity of acetylcholine receptors	(Harandi et al. 2015)

amnesia results from inhibition of AChE	and enhancing choline acetyltransferase expression	
Clinical trial on 15467 women divided into two groups 70 y or above and 20 - 59 y and five servings of supplementation of walnut/week	• Cognition scores improved in groups who consumed walnut as compared to the control	(Chauhan and Chauhan 2020)
Animal-based study: divided into four groups control, flax seed, aloe vera, and valproic acid and treated with water, 1.8ml/kg of flax seed oil, 0.4ml/kg of aloe vera, and 300 mg/kg of valproic acid given respectively for 3 weeks for flax seed oil and aloe vera and 2 weeks for valproic acid	• In oil and valproic acid treatment significantly increase the level of GABA, and anxiolytic effects were noticed • Flax seed and aloe vera treatment showed improvement in cognitive function and also decreased acetylcholine esterase activity	(Sarfaraz et al. 2020)
An experimental diet was given to female rats before conception during pregnancy and lactation, and female rats were divided into three groups flax seed, control, and modified control group after weaning offspring fed on the mother diet for 30 d	• Flax seed group offspring showed lower BMI and improved concentration of alpha-linolenic acid compared to the control group • Higher level of docosahexaenoic acid in the hippocampus compared to the modified control group and control group • Improved hippocampus DHA level showed better memory performance	(Fernandes et al. 2011)

Chia seeds offer health benefits, including decreasing cholesterol, blood clotting suppression, and preventing epilepsy and stress. Moreover, research suggests that eating chia seeds throughout pregnancy may help the baby's brain and retina grow better (Gupta and Mishra 2021). As a result, this research will use a chia intervention to investigate the impacts of chia seeds on cognitive skills.

According to scientists, the fundamental hypothesis that a chia-rich diet may improve cognitive skills has been verified. It was shown by two significant tests and the memory task, suggesting that consuming *Salvia hispanica* L. may improve memory skills. The authors were shocked by the substantial disparities in learning progress across the test groups. Further research is required to see whether these findings can be validated in the long run (Onneken 2018).

Walnut and Cognitive Function

Recent human and animal research indicates that long-term walnut supplementation may decrease the risk of MCI and AD onset/progression. An animal model of Alzheimer's disease showed that 28-42 g is the suggested serving of walnuts/per day (Chauhan and Chauhan 2020). Studies showed nutritional supplementation with walnuts (28-42 g) consumption per day in people affected AD-Tg mice's motor coordination, memory, learning abilities, and anxiety (Pandareesh et al. 2018).

The trial was conducted in Spain in which 437 adults (mean age: 65.9 years) and 522 people (mean age: 74.6 years) had a cardiovascular risk but did not develop CVD, and cognitive impairment was also noticed in these trials. They were supplemented with 28 g of mixed nuts/day (15g walnuts, 6.5g hazelnuts, and 6.5g almonds) and exposed to improved cognitive performance in the control group. Memory was significantly amended compared to the control group (Dreher 2018). The Mini-Mental State Examination (MMSE) and Clock Drawing Test (CDT) were used to evaluate global cognitive function after 6.4 years of nutritional involvement in the first research, but no baseline assessment was done. The second research compared results from six neuropsychological tests taken at baseline and after 4.2 years of dietary involvement to see if rates of cognitive improvement changed over time (Rajaram et al. 2017). Walnuts have the greatest antioxidant effectiveness among dry fruits, as shown by their high phenolic content, followed by almonds, cashew nuts, and raisins. According to another study, 50 g of walnuts contain considerably higher phenolic content than an 8-ounce drink of apple juice, a 5-ounce glass of red wine, or a milk chocolate bar (Campidelli et al. 2020).

Conclusions

A well-balanced diet, physical activity, and simple interactivity with the environmental component can influence our mental health and function. Some foods impact cognition by manipulating cellular processes or molecular systems, which are condemnatory for cognition and improved memory function. It offers the fascinating prospect that changes in diet might improve cognitive ability while preserving the brain from injury, encouraging healing, and counteracting the consequences of aging. According to new studies, the impact of food on the brain is intertwined with the impacts of other lifestyle factors like physical activity and sleep. The mutual effects of certain diets and physical activity on the stimulation of molecular processes involved in synaptic plasticity have significant suggestions for public health and therapeutic intervention design. The issue has received a lot of media interest due to the promising outcomes of clinical and preclinical research that revealed the positive impact of meals on the brain. Much of the information was unclear or overstated, contributing to people's anxiety about taking advantage of scientific advancements. Numerous dietary components have been proven to improve cognition; nevertheless, care is advised, as a well-balanced diet remains the foundation for any dietary supplementation. Similarly, popular dietary suggestions that may aid in weight loss are not always beneficial to the body's or mind's physiology.

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