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Aging Mechanism and Anti-Aging Foods for the Elderly: A Review

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Abstract

Living and eating healthiness have been the topic of interest for the elderly and their caregivers. Functional foods with balanced nutrition and anti-aging properties were considered and researched continuously. This review aimed to summarize and discuss the aging process and functional foods from natural sources for the elderly using studies conducted between 1996 and 2023 that focus on their effectiveness to alleviate aging symptoms. Aging is a complex process with various mechanisms including oxidative stress, hormonal system, activity of the enzyme sirtuin, and intestinal microbiota. The aging process leads to many disorders in the elderly such as Alzheimer's, Parkinson's, and non-communicable diseases. Additionally, it was found that balanced nutrients and energy along with the consumption of natural antioxidants from vitamins, phytochemicals, and sirtuin activator foods were effective at slowing down aging and extending an individual's lifespan. Recently, innovative research into foods for the elderly has focused on their sensory perception and whether they consist of the necessary nutrients. Therefore, this review might support a future perspective product of the food and pharmaceutical industries because of the different requirements of the elderly in society.

Keywords: Elderly, Aging Process, Anti-aging Food, Sirtuin Activator Foods, Diet Pattern

1. Introduction

The interesting forecast data from 2025 to 2050 of He *et al.* (2016) illustrates that the total global population will grow by about 34%, while the older population was estimated to almost double to 1.6 billion in the same period. The American Hospital Association (2008) estimated that the expense of treating age-related disorders would increase proportionally according to their severity with many hospital admissions expected (Association, 2008; Garza, 2016). Recently, numerous tactics have been implemented in anti-aging healthcare including behavior modification, public health, medical technology, and the management of facilities in care homes and gained attention (Leung *et al.*, 2013). It is widely recommended that the elderly and their caregivers engage in anti-aging behavior modification, particularly regarding their daily diet and meals, due to the easily accessible and beneficial health advantages. Dietary sources of energy, minerals, micronutrients, antioxidants, and phytochemicals are essential for the promotion of elderly health and the prevention of diseases associated with aging.

Consequently, the purpose of this review was to illustrate the aging mechanism and associated alterations. Moreover, the sources of anti-aging foods for the elderly, including natural antioxidant and sirtuin activator foods, were collected and represented. Dietary guidelines for the elderly, including calorie restriction, a balanced intake of macro- and micronutrients, and an anti-aging food pyramid, were presented and discussed. Trends in the development of food for the elderly were also highlighted in this work.

2. Aging mechanism

Some of the mechanisms of aging discovered by numerous research in recent years have been discussed. Fig 1 provides an illustration of the aging mechanism discussed in this review. In this review, we investigated several aging mechanisms that may be implicated in human physiology, such as oxidative stress, the endocrine system, sirtuin (SIRT) enzymes, the immune system, gut microbiota, and gene modulation.

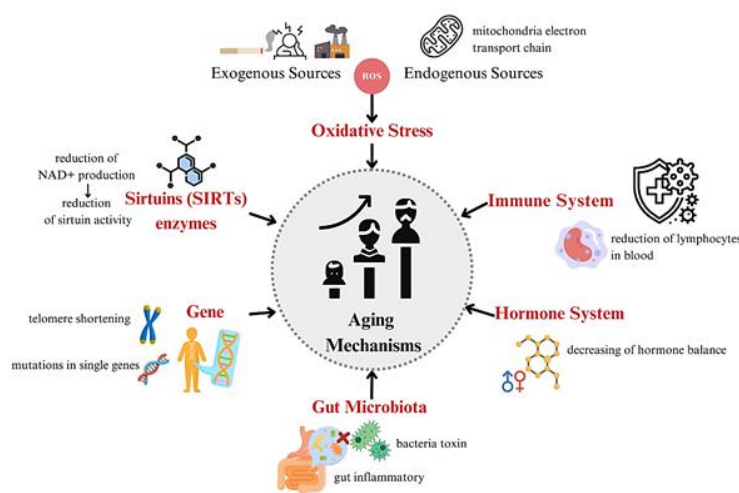


Fig 1 Mechanism of human aging.

2.1 Oxidative stress

Increasing oxidative stress is associated with the aging process, caused by an imbalance between the generation of free radicals and the body's ability to prevent them. The production of reactive oxygen species (ROS), also known as free radical derivatives of oxygen, results from the formation of potentially harmful byproducts. They are derived from both endogenous and exogenous sources (Phaniendra *et al.*, 2015). Beckman and Ames (1998) concluded that ROS is the cause of structural damage and that oxidative damage to macromolecules leads to age-related functional decreases.

2.2 Hormone system

According to the observation of Monzani *et al.* (2016), there was a possibility that there was a connection between the natural aging process and the regulation of hormones in the body. When the mechanism that controls sex hormones in men and women as part of ageing fails, it may contribute to changes in musculoskeletal and sexual dysfunction as well as long-term health disease concerns (El-Sakka Ahmed and Hassoba, 2006).

2.3 Sirtuins (SIRT) enzymes

Sirtuin, the family of histone deacetylases (HDACs), role in the mechanism of the aging process includes scleroderma, brain aging, and neurodegenerative disorders (Wyman and Atamas, 2018). The level of these enzymes decreases during aging while their regulation relieves the symptoms of cellular senescence (Grabowska *et al.*, 2017). SIRT can restore the balance of protein by reducing the accumulation of toxins, improving mitochondria function by reducing oxidative stress, and raising the level of nervous system function by elevating the transcription of learning and memory genes (Min *et al.*, 2013). Poulose and Raja (2015) summarized that humans encode seven sirtuin isoforms (SIRT1- SIRT7) with a variable intracellular distribution. Sirtuins have been linked to longevity, and evidence suggests that they have a role in a variety of diseases including cancer, diabetes, obesity, and neurodegenerative disorders. In addition, numerous studies have shown that the SIRT1-mediated deacetylation of targets has a substantial effect on mitochondrial function, apoptosis and inflammation. These processes and activities are critical for defining life span as well as the effect of an injury with reports indicating the relation of the latter to SIRT1 activity (Nakagawa and Guarente, 2011; Salminen *et al.*, 2008; Zhang *et al.*, 2010).

2.4 Immune system

Oliveira *et al.* (2010) discussed how immune system changes occur during the aging process. The changes due to aging are complicated and result in a decrease in certain immune response parameters, qualitative changes in response, and even the worsening of certain immunological processes. Nikolich-Zugich (2012) depicted how immune system aging affects the development of lymphocytes, originating within hematopoietic stem cells and their pluripotent progeny that will become lymphocytes.

2.5 Other aging mechanisms

Current research articles indicate the importance of the composition, diversity, and functional features of the intestinal microbiota in relation to aging-associated alterations (Vaiserman *et al.*, 2017). Age-related disorders in the gut microbiome are an important pathological state, and touch on neurodegeneration and cardiovascular disease (Friedland, 2015; Sanduzzi *et al.*, 2016). Some of the articles represent key

findings pathways that support an epigenetic role in aging (Sen *et al.*, 2016). Recent studies have demonstrated a genetic involved to human aging and longevity. Rodríguez-Rodero *et al.* (2011) reviewed that mutations in certain genes have been found to provide greater resistance to stress and a slower rate of damage accumulation, resulting in increased longevity. Zhang *et al.* (2023) presented an understanding of how mutations in single genes can significantly impact lifespan and provided an example of Eriksson *et al.* (2003) that demonstrated that Lamin A, a major constituent of the nuclear matrix, has mutations in exon 11 of the LMNA gene that can impair nuclear structure and function, resulting in premature aging. Additionally, Telomeres, which are DNA-protein complexes that cap the ends of linear DNA strands, serve to stabilize the chromosomes and prevent instability. There is a correlation between telomere shortening and the decline of somatic stem cells during the aging process (Collado *et al.*, 2007; O'sullivan and Karlsederl, 2010)

3. Aging-related diseases and symptoms

Aging is associated with wrinkles, decreased brain function, and an increased risk of chronic disease. Interestingly, sarcopenia can be a risk factor of dysphagia in the elderly (mean age 82.5 ± 8.4 years) because of a loss of skeletal muscle mass and decreased muscle strength which results in a decreased swallowing function (Maeda and Akagi, 2016). The memory functions of the elderly, mainly verbal such as digit span, word span, and story recall, normally decline with aging. Alzheimer's disease and Parkinson's disease are the most common causes of *dementia*. Low testosterone level is relatively associated with an increased risk of worse cognitive function and Alzheimer's disease among elderly men (Lv *et al.*, 2016). Several changes in the cardiovascular system during the normal aging process, including changes in the structural components in the arteries, decreasing vascular elasticity, and abnormality of the endothelium of aged vessels, lead to specific cardiovascular diseases in the elderly. Moreover, some non-communicable diseases (NCDs) are risk factors for coronary heart disease such as diabetes, obesity, and hypertension (Jackson and Wenger, 2011). Metabolic syndrome in older people was largely (73.1%) associated with cardiovascular risk by considering the relationship between body mass index and cardiovascular disease (Dhana *et al.*, 2016).

Various researchers are driven to discover solutions to age-related diseases and symptoms, such as anti-aging drugs, herbal supplements, and artificial intelligence (AI) technology. This article concentrates on food and related topics as potential solutions. Nevertheless, there are limitations and important factors contributing to decreased appetite and food intake of elderly people such as physical, mental, swallowing and mastication difficulties. Physical functioning (e.g., activities of daily living, leisure and social activities, general physical activities, etc.) is essential for food security among elderly individuals, and thus resources should be provided to enable the acquisition, preparation, and consumption of food for those with physical impairments (Jackson *et al.*, 2019). In the meantime, Rusu *et al.* (2020) emphasized the importance of regularly assessing the overall nutritional status (e.g., body weight, lean body mass, etc.) and effectively communicating the need for nutrient supplementation.

Furthermore, a considerable amount of research has been investigating the correlation between the diverse backgrounds of the elderly and their food sources. The behavior of elderly individuals from different backgrounds, such as urban and rural areas, is a contributing factor to the successful implementation of food personalization. Gao *et al.* (2022) suggested that elderly people living in rural areas may improve their health by advocating intergenerational cohabitation, increasing their consumption of fruits and vegetables, and maintaining their intake of protein to achieve a balanced diet. Interestingly, there was a notable correlation between the proximity to the nearest food store and the dietary variety of elderly people living in rural areas. These results indicate the necessity of interventions in areas that are at a higher risk of having a limited dietary variety, such as those located far away from food stores. (Gomi *et al.*, 2022). Fushimi *et al.* (2023) has demonstrated that there is a strong correlation between dietary intake of food and nutrients, physical performance, and physical activity among elderly living in urban areas. There was a significant positive correlation between the physical functions (movement function, static balance, and walking function) and the intake of vegetables, seeds, fruits, and milk; as well as with magnesium, potassium and vitamin B6 and with the dietary fiber/carbohydrate composition ratio.

Thus, this article not only provided a compilation of anti-aging foods, but also proposed a suitable dietary pattern for the elderly, taking into consideration any potential restrictions they may have.

4. Anti-Aging Foods for Elderly

Powerful anti-aging foods are enormous sources of essential minerals, vitamins, antioxidants, and bioactive compounds that have a powerful ability to affect the anti-aging process. This article reviews several Asian and Mediterranean foods that affect aging-related diseases.

Curcumin, a polyphenol isolated from natural turmeric, has many pharmacological abilities including antioxidant, anti-inflammatory, anticancer, and neuroprotective activities. Curcumin consumption improves cognitive activity and ameliorates age-related spatial memory deficits among elderly people because the tropomyosin receptor kinase B (TrkB) signals the derived neurotrophic factor upregulation (Farooqui and Farooqui, 2019).

Catechin in green tea (GTC) has a 20-30 times higher level of anti-oxidative activity in comparison to blueberries and strawberries. Recently, GTCs were of high interest in terms of pharmacological activities to prevent age-related neurodegeneration including Parkinson's disease and Alzheimer's disease (Farzaei *et al.*, 2019). Green tea consumption has been widely suggested to treat age-related diseases in the elderly because of its potential effects on neurodegenerative diseases, markedly Alzheimer's and Parkinson's (Tomata *et al.*, 2016). The main tea polyphenol in green tea is epigallocatechin gallate (EGCG). Its mechanism can disrupt the amyloid plaque formation in the brain parenchyma through multiple pathways, which can be a cause of Alzheimer's disease (Murphy and LeVine, 2010). Green tea consumption for 12 months might prevent an increase of oxidative stress in the elderly but this might not affect cognitive function (Ide *et al.*, 2015).

Garlic's benefits have a good effect on disorders of the cardiovascular, respiratory, and peripheral nervous systems. The sulfur compounds in garlic act on the signaling pathways of arthritis (Pareek *et al.*, 2019). Also, the bioactive compounds in ginger have therapeutic potential in the treatment of age-related neurological disorders (Choi *et al.*, 2018). Knee osteoarthritis inflammation could be reduced in patients through the supplementation of ginger powder at a dose of one gram per day (Naderi *et al.*, 2015). *Centella Asiatica* was discussed and determined to be the main memory supporter in addition to the research evidence on several mechanisms underlying its neuroprotective properties (Sabaragamuwa *et al.*, 2018).

Perilla seed oil is a rich source of omega-3 polyunsaturated fatty acids, specifically alpha-linolenic acid (ALA) (Dhyani *et al.*, 2019). ALA has a minimal effect on sarcopenia in older men (Cornish and Chilibeck, 2009). Perilla seed oil helps to provide neuroprotection against mild to moderate dementia, although it seems not to improve cognitive function in preclinical studies. Also, perilla seed oil can reduce both total cholesterol and LDL cholesterol. Black sesame seed oil also contains sesamin compounds which are important to the elderly due to their anti-inflammatory and chondroprotective nature. Sesamin has the beneficial effects of lessening apoptosis, astrogliosis, and oxidative stress (Baluchnejadmojarad *et al.*, 2017).

Tropical fruits with anti-aging properties may offer low-calorie and rich essential vitamins for the elderly. Avocado includes important micronutrients such as vitamin C, vitamin A, vitamin E, vitamin B6, magnesium, and folate (Weaver, 2013). Furthermore, several phytochemicals were also found in the fruit and seeds of the avocado. Large amounts of alpha-tocopherol and beta-sitosterol were found in avocado pulp oil (dos Santos *et al.*, 2014). Alpha-tocopherol has an effect on the formation of ROS in the inflammatory processes and enhances immune function (Capuron *et al.*, 2009). Also, beta-sitosterol contributed to suppressing carcinogenesis (Bouic, 2002). The bioactive compounds in avocado could prevent cardiovascular disease and reduce cholesterol (Duarte *et al.*, 2016). Moreover, dragon fruits are also tropical super fruits because of their many health benefits including the ability to improve digestion, fortify the immune system, prevent diabetes, and decrease the risk of breast cancer (Poolsup *et al.*, 2017).

Colored or pigmented rice grains include mainly red, purple, and black rice. They include a variety of antioxidant substances including flavones, tannins, phenolic, sterols, oryzanols, and essential oils (Poomipak *et al.*, 2018). Gamma oryzanol is an especially important antioxidant found in colored rice bran and rice bran oil, which is mainly composed of trans-ferulic acid esters of lipophilic phytosterols (Sing *et al.*, 2015). According to studies, black and purple rice have shown contain two to three times more gamma oryzanol than white rice (Boonsit *et al.*, 2010). Saenjum *et al.* (2012) reported that purple rice bran from glutinous cultivars in Northern Thailand had ability to inhibit nitric oxide production and act as a lipophilic radical scavenger more effectively than a hydrophilic radical scavenger. Suantai *et al.* (2022) demonstrated that red jasmine rice harvested in Chiang Mai, Thailand had antiviral activity against both herpes simplex virus type 1 (HSV-1) and type 2 (HSV-2), as well as exhibiting anticancer properties. Thus, it was suggested that purple rice bran is a powerful natural compound with antioxidant, anti-inflammatory and anticancer properties. A large amount of data has indicated the potential for there to be anti-inflammation,

anticancer, and anti-aging processes due to the major components found in pigmented rice, especially germ and bran extracts (Limtrakul *et al.*, 2019). Rice berry (*Oryza sativa*), purple-pigmented rice, could significantly prevent memory impairment and reduce the risk of Alzheimer's disease (Pannangrong *et al.*, 2011).

4.1. Natural Antioxidants

The elderly and their caregivers have raised safety concerns about the use of synthetic antioxidants in convenient food products. The uptake of natural antioxidants from foods such as fruits, vegetables, and herbs is the best choice for the elderly because of their safety compared to synthetic antioxidants (Li *et al.*, 2014). Generally, natural antioxidants can scavenge free radicals and maintain the balance of homeostasis in the human body. It is common knowledge that these natural antioxidants assist in the reduction of chronic diseases due to their health-promoting qualities. Lourenço *et al.* (2019) classified natural antioxidants from plants into three main classes, phenolic compounds, vitamins, and carotenoids. Common natural antioxidants from dietary sources may have the potential to be therapeutic in relation to age-related conditions. An example is given in Table 1.

Table 1 Some dietary antioxidants and their functions to delaying in age-related diseases.

Antioxidant Compounds	Natural Sources	Age-related diseases.	References
Carotene	carrots, yellow papaya, spinach, sweet potato and pumpkin	Eye diseases	(Kowluru <i>et al.</i> , 2014)
Vitamin C (Ascorbic acid)	citrus fruits, spinach, garlic, cabbage, cantaloupe and strawberries	Cardiovascular disease and cancer	(Passoni and Coelho, 2008)
Vitamin E (α -Tocopherol)	vegetable and seed oils, nut and legumes, avocado	Lung, skin and prostate cancers	(Quin <i>et al.</i> , 2005)
Lycopene	red tomatoes, watermelons, papaya, pink grapefruit and pink guava	Alzheimer's disease and Parkinson's disease	(Liu <i>et al.</i> , 2013; Min and Min, 2014)
Flavonoids	apple, onions, green tea, red wine, soy products and black beans	Cardiovascular disease, arthritis, and Alzheimer's disease	(Khan <i>et al.</i> , 2014; Zhang <i>et al.</i> , 2014)
Coenzyme Q10	oily fish (such as salmon and tuna), organ meats (such as liver), and whole grains.	Coronary artery diseases	(Lee <i>et al.</i> , 2013; Saini, 2011)

4.2 Sirtuin Activator Foods

Sirtuin foods seem to have become a trendy new diet scheme associated with sirtuins and longevity. The dietary activators of Sirt1 have been widely investigated recently. Polyphenols such as resveratrol and anthocyanin have been reported to activate AMPK, an effect that may activate SIRT (Villalba and Alcain, 2012). Resveratrol, a SIRT1 activator, may be used for the prevention of obesity, tumorigenesis, and aging-related deterioration in heart function and neuronal loss. It has been illustrated that resveratrol can enhance the lifespan through inducing and activating SIRT1 activity and increasing the SIRT1 affinity for both NAD⁺ and the acetylated substrate. Furthermore, CR with a resveratrol intake exhibited similar anti-aging activities related to SIRT1 and showed an improvement in cognitive performance (Rouse and Egan, 2018). Piceatannol is a natural source. It is a hydroxylated derivative of resveratrol that has been used as a food additive and herbal medicine in Asia. Additionally, it has been shown to have anti-cancer properties (Potter *et al.*, 2002; Yokozawa and Kim, 2007).

Recent research has indicated that sirtuin-activating compounds such as luteolin, butein, piceatannol, fisetin, quercetin, and resveratrol have a stimulatory effect on the Sir2 activity in yeast. Some of the research reports indicate that a dietary intake of omega-3 fatty acids has the potential to reverse the decline of Sirt1 in rats with a mild traumatic brain injury (Chen *et al.*, 2018). Anthocyanidins can also greatly increase SIRT6 deacetylation activity in vitro. Moreover, cyaniding can upregulate SIRT6 protein expression in human colon adenocarcinoma Caco-2 cells (Rahnasto-Rilla *et al.*, 2018). Interestingly, Khan *et al.* (2021) proposed that SIRT activators can be investigated to determine their effectiveness of alleviating COVID-19 symptoms. Table 2 is a review of the sirtuin-activating compounds that are found in natural food.

Table 2 Sirtuin-activating compounds in sirtuin stimulation and food sources of sirtuin activators.

Sirtuin-activating Compounds	Dietary Sources	References
Resveratrol	grapes, red wine, berries, peanuts, and dark chocolate	(Allard <i>et al.</i> , 2009)
Anthocyanidin	red berries including bilberry, raspberry and cranberry	(Rahnasto-Rilla <i>et al.</i> , 2018)
Butein	butea, dahlia, coreopsis and searsia	(Semwal <i>et al.</i> , 2014)
Piceatannol	red wine, passion fruit, polygonum cuspidatum, rhodomyrtus tomentosa, white tea and peanut	(Kukreja <i>et al.</i> , 2013)
Fisetin	strawberry, apple, persimmon, grape, onion, and cucumber	(Khan <i>et al.</i> , 2013)
Quercetin	onions, green tea, green pepper, asparagus, red leaf lettuce and tomatoes	(Nishimuro <i>et al.</i> , 2015)
Curcumin	turmeric	(Stanić, 2017)
Luteolin	broccoli, pepper, thyme, celery, parsley, rosemary and bird's-eye chilies	(Miean and Mohamed, 2001; Shamsizadeh <i>et al.</i> , 2017)

5. Suggested diet pattern for elderly

5.1 Calorie restriction (CR)

CR is defined as a long-term dietary intervention (Anderson and Weindruch, 2012) whereby there is a limit in calories and malnutrition is avoided. CR, which can extend the human lifespan by up to five years, has quietly become accepted among leading researchers (Dar *et al.*, 2012). CR intake and the high physical activity levels of an elderly population of Okinawans generated a low Body Mass Index (BMI) relative to the high plasma levels of DHEA (Dehydroepiandrosterone Hormone). This could reduce the fatalities from age-related diseases such as cancer of the prostate, breast, and colon, and coronary heart disease (Willcox *et al.*, 2007). However, for elderly people, there may not be an understanding of the relationship between obesity and its adverse outcome. The relative risk is associated with BMI failure in old age (Stevens *et al.*, 1998). Besides controlling the balance of physical activity with food supplements, an elderly person should try to have a diet that is diverse and nutrient-rich (Tripathi *et al.*, 2016).

Furthermore, CR- mimetics in elderly people should be examined as a powerful alternative for the maintenance of health. CR-mimetics work with the caloric restriction between activated biochemical pathways in mammalian cells through various polyphenols which include resveratrol, catechins, quercetin, and genistein, which is found in plants (Morris, 2010).

5.2 Balanced intake of macro-micronutrients

However, CR for elderly people should also relate to the contributors of macronutrients which include protein, carbohydrates, and fat as total energy. A good amount of knowledge on the determinants of nutritional intake may help in the early prevention of malnutrition. Macronutrient intake for the elderly in the literature is as shown in Table 3.

Table 3 Contributors of macronutrient intakes as total energy for the elderly person

Contributors of Macronutrient intakes (% calories)			References
Protein	Carbohydrates	Fat	
10-15	55-60	25-30	(Bureau of Food, 2012)
10-35	55-75	20-35	(Ter Borg <i>et al.</i> , 2015)
10-35	45-65	20-35	(Services, 2017)
24-26	61-59	15	(Saito <i>et al.</i> , 2018)

The presence of the above disorders may increase or decrease because of dietary adjustments and the calories and micronutrients involved. Vitamin A is important for vision, bone improvement, and immune function. Vitamin D with a calcium intake together with physical activity can improve functional capacity and femoral bone density which can decrease the risk of falls among elderly people (Bunout *et al.*, 2006). A calcium balance is also important for older people because it can maintain bone strength and keep bones healthy during older age. However, it should be noted that vitamin K intake is associated with gastrointestinal symptoms and constipation (Shah *et al.*, 2014). The current dietary reference intake for vitamin E should be raised for the elderly because it has anti-inflammatory and immune

function benefits related to the processes and resistance to infection. Total B vitamin supplementation including vitamins B12, B6, B2 and folate is associated with a mild cognitive function impairment among elderly Koreans (Kim *et al.*, 2014). The elderly population often avoids eating meats and other foods that contain zinc to avoid increasing their blood cholesterol levels due to the many associated recommendations. However, this results in a zinc deficiency among the elderly. Elderly people have to restrict their intestinal absorption, so then they can increase their utilization of refined wheat products, which lack in zinc and other fiber-rich foods that contain phytate (Cabrera, 2015)

5.3 Anti-aging food pyramid

The elderly population should be recommended daily servings consisting of macro and micronutrients, bioactive compounds, antioxidants, and other essential compounds for anti-aging which can be found in this article. Notably, the Anti-Aging Diet Pyramid was applied to intake servings and CR for the elderly (Shakti and Dubey, 2015). The Anti-Aging Diet Pyramid is a food pattern made up of dietary habits that will lead to longevity. The sources of the anti-aging diet are described in Fig 2.

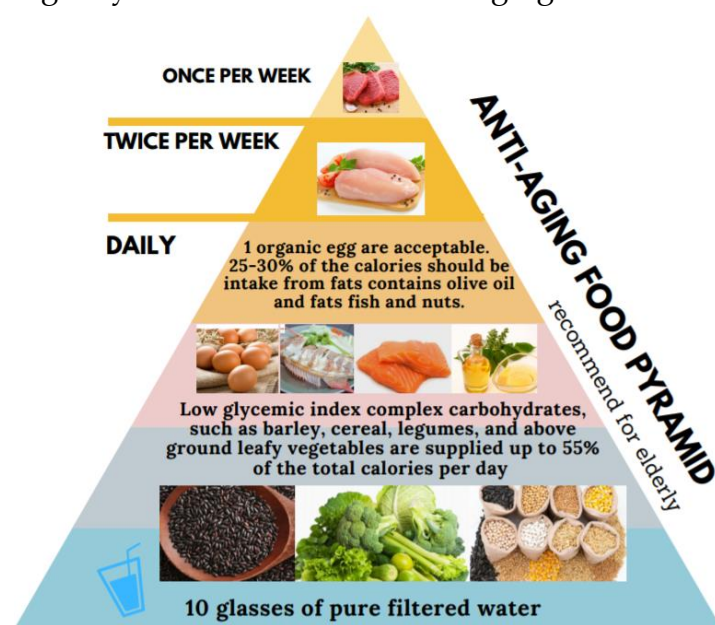


Fig 2 The anti-aging food pyramid can apply to calorie intake for the elderly. Modified from Shakti and Dubey (2015)

The pyramid is divided into 3 layers including daily, once per week, and twice per week. Beginning each day with 10 full glasses of clean and filtered water is the first stage of the pyramid. In addition, complex carbs, which provide up to 55 percentage of the total calories. These carbs are of the low-glycemic index varieties and include barley, grains, legumes, and vegetables with leafy greens. A suitable source of protein for the daily layers of the foundation diet is one egg per day. The majority of the lipids in the diet should come from olive oil, which is rich in monounsaturated fats and an excellent source of antioxidants. According to the anti-aging food pyramid, olive oil, fish, and nut fats should account for 25 to 30 percentage of daily calories. The second layer is a considerably thinner layer that consists of protein-rich foods derived from fish and poultry. The elderly need to eat

protein-rich foods from this group at least twice every week. In the third layer, elderly should obtain sweets and lean red meat once a week. This suggested diet pattern can be applied to help develop food products for the elderly to satisfy the balance of micro-macro nutrients that also have a high potential of antioxidants and antiaging ingredients.

The summary of the reviews from multiple research studies linked to diet include calorie restrictions, nutrients, micronutrient intakes, and sirtuin foods in relation to the aging mechanism as shown in Fig 3.

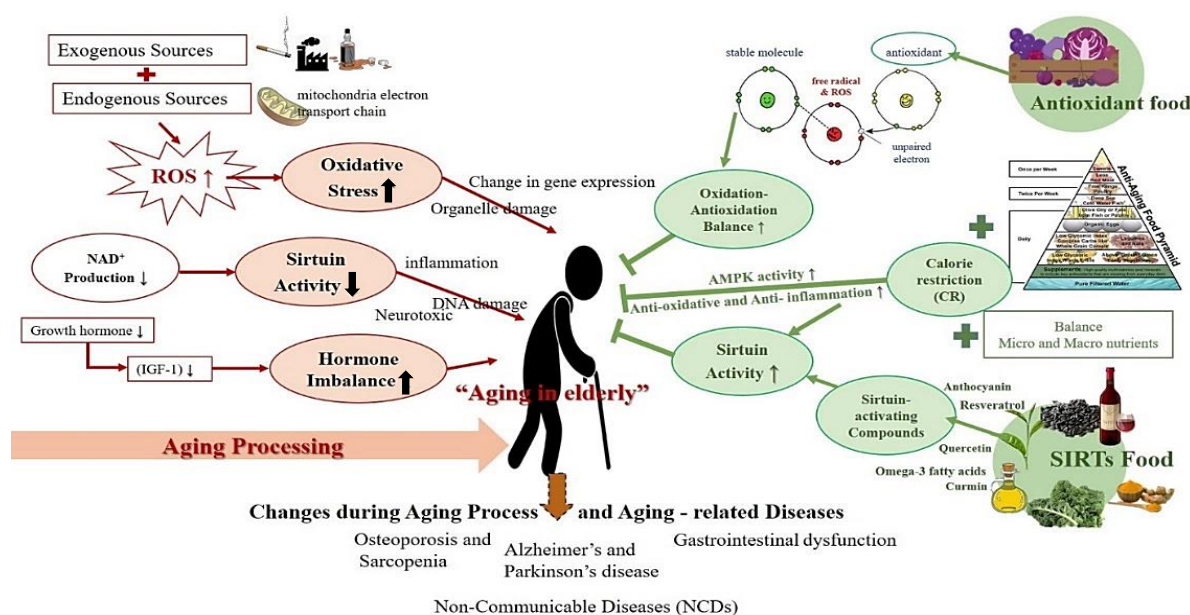


Fig 3 Association between aging mechanisms and benefits of food sources on anti-aging ability.

In red, arrows show the three main aging mechanisms that simulate many disorders in the elderly that consist of increasing oxidative stress, decreasing sirtuin activity, and hormone balance, as described in the previously part. The aging process is linked to increased oxidative stress, ROS can come from both exogenous and endogenous causes. Exogenous or environmental sources such as air pollution, tobacco smoke, ionizing and nonionizing radiation, meals, medications, and xenobiotics (Bhattacharyya *et al.*, 2014). Endogenous sources include cellular metabolic activities such as oxidases (NOXs), nicotinamide adenine dinucleotide phosphate hydrogen (NADPH) and xanthine oxidases (XO), among other substances, according to Aranda-Rivera *et al.* (2022). Imai and Guarente (2016) reported that the family of proteins known as “sirtuins” has a special characteristic in that it couples the breakdown of nicotinamide adenine dinucleotide (NAD⁺) and protein deacetylation. This strong relationship between NAD⁺ and sirtuins has provided invaluable a molecular explanation for how to control aging and longevity in a variety of animals by regulating energy metabolism. According to reports of Poulouse and Raju (2015), sirtuin1 activity declines with age, and enhanced sirtuin expression or activation has been linked to longer lifespans. In addition, hormones function as chemical

messengers that link and regulate all significant cellular metabolic, growth, and developmental processes. The control of hormonal availability of their active products may be related to the aging process (Monzani *et al.*, 2016). The hormone known as Insulin-like growth factor-1 (IGF-1), which majorly regulates growth hormone (GH)-stimulated somatic growth, was the subject of numerous investigations. When the mechanism to regulate sex hormones in both men and women ages fails, it may affect musculoskeletal and sexual dysfunction as well as long-term risks of health problems (El-Sakka Ahmed and Hassoba, 2006).

The green text and arrows show the suggested foods and diet patterns that can slow down the aging process and relieve aging symptoms. According to various research, foods with high in antioxidants have an anti-aging effect. It is expected that various antioxidants found in food would help to regulate the redox balance because the body's ability to regulate redox balance is a key aspect of aging (Miyazawa *et al.*, 2022). A recommended diet for the elderly includes caloric restriction along with a balance of micro and macronutrients. CR has the ability to activate AMP-activated protein kinase (AMPK). AMPK is an energy sensor that reduces the kinase activity of the autophagy repressor mechanistic target of rapamycin (mTOR) when CR is present. Moreover, CR both directly and indirectly activates sirtuins, which are nicotinic adenine dinucleotide (NAD⁺)-dependent lysine deacetylases (KDACs) that play essential roles in anti-aging process (Cantó and Auwerx, 2011; Guarente, 2007). According to Kökten *et al.* (2021), CR also induces a change in the composition of the gut microbiota and favors bacteria that produce anti-inflammatory. SIRT6 plays key roles in the treatment and prevention and age-related metabolic disorders. Various foods contain numerous potential modulators of SIRT6, especially polyphenols, which are anti-inflammatory and anti-aging.

6. Trends when developing food products for the elderly

Developing innovative foods should reach an interesting and increasing segment of the elderly consumer market globally. “Anorexia of aging” refers to their eating and swallowing problems, as well as dry mouth, taste loss, and malnutrition. Many food entrepreneurs need to develop innovative foods for the elderly to meet their nutritional requirements, provide texture-modified foods, and provide acceptable solutions to overcome their eating and swallowing difficulties (Lutz *et al.*, 2019). The nutritive value of the product portions with selected functional ingredients, vitamins, and minerals is the key to developing food products for the elderly. The design product concept of ready-to-eat, easy-to-open, and easy-to-bite and chew foods will support their nutritional and functional needs (Baugreet *et al.*, 2017; Rusu *et al.*, 2020).

Healthy texture modified (TM) or texture-softening foods for the elderly are a major challenge for product development. TM foods refer to foods that have been physically or chemically modified to create a softer texture, which is recommended for dysphagia diets as it reduces the risk of choking. These foods should be soft, moist, elastic, smooth, and easy to swallow (Cichero *et al.*, 2013; Yoshioka *et al.*, 2016). For elderly with dysphagia, replicating human tactile perception in terms of hardness, adhesiveness, and cohesiveness can be utilized for the development of a food products (Nishinari and Fang, 2018). Costa *et al.* (2019) explained the phenomenon of food

texture alteration typically involves a step of dilution with water or other liquids during the blending and/or size reduction processes. In addition, several known technologies can produce TM foods including enzymatic treatments, freeze-thawing infusions, high pressure processing, pulsed electric fields, and sonication (Aguilera and Park, 2016). For example, Ma *et al.* (2019) applied treatment sequences of a high pressure processing and papain combination can significantly influence the tenderization effect on yak meat. Chao *et al.* (2022) conducted research to alter the consistency of chicken surimi by combining it with mealworm protein isolate, and coaxial three-dimensional printing was utilized to create a fibrous structure suitable for consumption by the elderly. It is remarkable that this study was able to successfully modify the texture of surimi to create a novel food product with a fibrous shape suitable for elderly consumption.

In addition, numerous studies have been conducted to improve the extraction efficiency of bioactive compounds that support anti-aging via various pathways, such as antioxidants, anti-inflammatory, and anti-cancer, from natural plants and herbs such as turmeric rhizomes, Jasmine rice bran protein hydrolysate, black and golden garlic, black rice grain, Assam green tea, and Lingzhi (Chuensun *et al.*, 2020; Hunsakul *et al.*, 2022; Pakakaew *et al.*, 2022; Salee *et al.*, 2022; Singh, Srichairatanakool, Chewonarin, Brennan, *et al.*, 2022; Singh, Srichairatanakool, Chewonarin, Prommaban, *et al.*, 2022).

Functional foods are ingredients that offer additional health benefits in addition to their nutritional value or may contain supplements or other components designed to improve health (Grochowicz *et al.*, 2021). Functional food is becoming increasingly attractive to both the elderly and their caregivers as a means of promoting a high quality of life. Numerous studies have proposed and advocated for the use of various functional foods to aid the elderly in enhancing their nutritional status and avoiding deficiencies. Arnold *et al.* (2021) has reviewed that the intake of calcium is essential, and chicken eggshell powder has been applied in food products to provide a high daily calcium content. Recently, the market has seen the introduction of various functional products, such as bread enriched with omega-3, which can help to reduce cholesterol levels due to its high content of soluble fiber, and low-fat muesli yoghurt, which can help to lower blood glucose. (Ashwell, 2004; Kalra, 2003). Similarly, Thai researchers have been interested in exploring and creating functional foods for general consumers, particularly for the elderly. For example, Chompoorat and Phimpimol (2019) formulated a functional cupcake for elderly utilizing red kidney bean flour as a main component with a high concentration of protein and fiber, and consuming a single portion of this cupcake could provide 8% of the Daily Recommended Intake of protein. Samappito (2021) developed purple waxy corn milk yogurt prepared from purple waxy corn which is considered to be one of the potential probiotic foods. Moreover, Ngampeerapong *et al.* (2022) investigated methods to reduce sugar and increase fiber content in Thong Ake, a Thai traditional auspicious dessert composed of sugar, flour, coconut milk, and egg yolk, which could potentially be a risk factor for non-communicable diseases. The mixture of stevioside and sorbitol, as well as resistant starch, were taken into consideration. The Thai dessert developed is suitable for those who wish to restrict their carbohydrate consumption, particularly the elderly.

Consequently, the prospective development of functional foods for the elderly should consider several factors that have been illustrated in Figure 4. The developed functional foods for the elderly should have a high anti-oxidant and anti-aging effect based on a balance of micro and macronutrients. Specifically, the improved healthy texture should be examined because it contributes to the positive emotional state of the elderly when consuming functional foods.

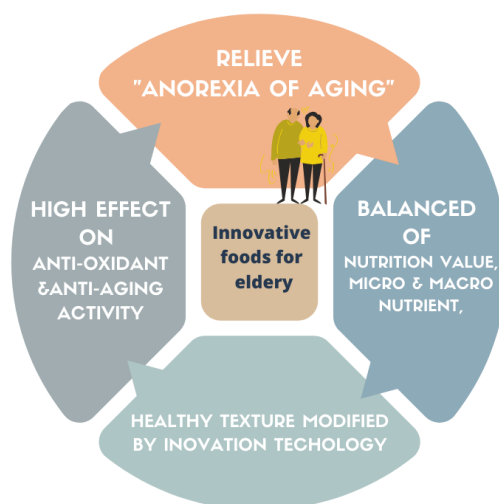


Fig 4 Perspective concept for the functional food development for the elderly.

4. Conclusion

Dietary behavior modification as an anti-aging strategy is essential for the health of the elderly and the prevention of age-related disorders. It is suggested that the diet of the elderly includes daily dietary portions with balanced macro- and micronutrients, bioactive components, antioxidants, and other anti-aging compounds, especially sirtuin activator foods. Due to the variety of anti-aging foods and their benefits, the development of anti-aging products that are considered to be age-related is an interesting topic for the future. The study of the link between innovative anti-aging products and their effects on the aging mechanism, especially in the elderly, should be investigated.

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References

- Aguilera, J. M. and Park, D. J. 2016. Texture-modified foods for the elderly: Status, technology and opportunities. *Trends in Food Science & Technology*. 57: 156-164. <https://doi.org/10.1016/j.tifs.2016.10.001>.
- Allard, J. S., Perez, E., Zou, S. and de Cabo, R. 2009. Dietary activators of Sirt1. *Molecular and Cellular Endocrinology*. 299(1): 58-63. <https://doi.org/10.1016/j.mce.2008.10.018>.

- Anderson, R. M. and Weindruch, R. 2012. The caloric restriction paradigm: implications for healthy human aging. *American Journal of Human Biology*. 24(2): 101-106.
- Aranda-Rivera, A. K., Cruz-Gregorio, A., Arancibia-Hernández, Y. L., Hernández-Cruz, E. Y. and Pedraza-Chaverri, J. 2022. RONS and Oxidative Stress: An Overview of Basic Concepts. *Oxygen*. 2(4): 437-478.
- Arnold, M., Rajagukguk, Y. V. and Gramza-Michałowska, A. 2021. Functional food for elderly high in antioxidant and chicken eggshell calcium to reduce the risk of osteoporosis-a narrative Review. *Foods*. 10(3): 656.
<https://doi.org/10.3390/foods10030656>.
- Ashwell, M. 2004. Concepts of functional food. *Nutrition & Food Science*. 34(1): 47-47. <https://doi.org/10.1108/nfs.2004.34.1.47.3>.
- Association, A. H. 2008. 64-How Boomers Will Change Health Care (2007). Chicago, IL: American Hospital Association & First Consulting Group.
- Baluchnejadmojarad, T., Mansouri, M., Ghalami, J., Mokhtari, Z. and Roghani, M. 2017. Sesamin imparts neuroprotection against intrastriatal 6-hydroxydopamine toxicity by inhibition of astroglial activation, apoptosis, and oxidative stress. *Biomedicine & Pharmacotherapy*. 88: 754-761.
- Baugreet, S., Hamill, R. M., Kerry, J. P. and McCarthy, S. N. 2017. Mitigating nutrition and health deficiencies in older adults: a role for food innovation. *Journal of Food Science*. 82(4): 848-855.
<https://doi.org/https://doi.org/10.1111/1750-3841.13674>.
- Beckman, K. B. and Ames, B. N. 1998. The free radical theory of aging matures. *Physiological Reviews*. 78(2): 547-581.
- Bhattacharyya, A., Chattopadhyay, R., Mitra, S. and Crowe, S. E. 2014. Oxidative stress: an essential factor in the pathogenesis of gastrointestinal mucosal diseases. *Physiological Reviews*. 94(2): 329-354.
<https://doi.org/10.1152/physrev.00040.2012>.
- Boonsit, P., Pongpiachan, P., Julsrigival, S. and Karladee, D. 2010. Gamma oryzanol content in glutinous purple rice landrace varieties. *Chiang Mai University Journal of Natural Sciences*. 9: 151-158.
- Bouic, P. J. D. 2002. Sterols and sterolins: new drugs for the immune system. *Drug Discovery Today*. 7(14): 775-778.
- Bunout, D., Barrera, G., Leiva, L., Gattas, V., de la Maza, M. P., Avendaño, M. and Hirsch, S. 2006. Effects of vitamin D supplementation and exercise training on physical performance in Chilean vitamin D deficient elderly subjects. *Experimental Gerontology*. 41(8): 746-752.
<https://doi.org/https://doi.org/10.1016/j.exger.2006.05.001>.
- Bureau of Food, F. a. D. A. 2012. Smart consumption choices with sweet, salty labels. In.
- Cabrera, A. J. R. 2015. Zinc, aging, and immunosenescence: an overview. *Pathobiology of Aging & Age-related Diseases*. 5(1): 25592.
- Cantó, C. and Auwerx, J. 2011. Calorie Restriction: Is AMPK a Key Sensor and Effector. *Physiology*. 26(4): 214-224.
<https://doi.org/10.1152/physiol.00010.2011>.

- Capuron, L., Moranis, A., Combe, N., Cousson-Gélie, F., Fuchs, D., De Smedt-Peyrusse, V., Barberger-Gateau, P. and Layé, S. 2009. Vitamin E status and quality of life in the elderly: influence of inflammatory processes. *British Journal of Nutrition*. 102(10): 1390-1394.
- Chao, C., Hwang, J. S., Kim, I. W., Choi, R. Y., Kim, H. W. and Park, H. J. 2022. Coaxial 3D printing of chicken surimi incorporated with mealworm protein isolate as texture-modified food for the elderly. *Journal of Food Engineering*. 333: 111151. <https://doi.org/https://doi.org/10.1016/j.jfoodeng.2022.111151>.
- Chen, X., Pan, Z., Fang, Z., Lin, W., Wu, S., Yang, F., Li, Y., Fu, H., Gao, H. and Li, S. 2018. Omega-3 polyunsaturated fatty acid attenuates traumatic brain injury-induced neuronal apoptosis by inducing autophagy through the upregulation of SIRT1-mediated deacetylation of Beclin-1. *Journal of Neuroinflammation*. 15(1): 310. <https://doi.org/10.1186/s12974-018-1345-8>.
- Choi, J. G., Kim, S. Y., Jeong, M. and Oh, M. S. 2018. Pharmacotherapeutic potential of ginger and its compounds in age-related neurological disorders. *Pharmacology & Therapeutics*. 182: 56-69. <https://doi.org/https://doi.org/10.1016/j.pharmthera.2017.08.010>
- Chompoorat, P. and Phimpimol, J. 2019. Development of a Highly Nutritional and Functional Gluten Free Cupcake with Red Kidney Bean Flour for Older Adults. *Food and Applied Bioscience Journal*. 7(3): 16-26.
- Chuensun, T., Chewonarin, T., Laopajon, W., kawee-ai, A., Walter, P. and Utamaang, N. 2020. Comparative evaluation of physicochemical properties of Lingzhi (*Ganoderma lucidum*) as affected by drying conditions and extraction methods. *International Journal of Food Science & Technology*. 56(6): 2751-2759. <https://doi.org/10.1111/ijfs.14906>.
- Cichero, J. A. Y., Steele, C., Duivesteyn, J., Clavé, P., Chen, J., Kayashita, J., Dantas, R., Lecko, C., Speyer, R., Lam, P. and Murray, J. 2013. The Need for International Terminology and Definitions for Texture-Modified Foods and Thickened Liquids Used in Dysphagia Management: Foundations of a Global Initiative. *Current Physical Medicine and Rehabilitation Reports*. 1(4): 280-291. <https://doi.org/10.1007/s40141-013-0024-z>.
- Collado, M., Blasco, M. A. and Serrano, M. 2007. Cellular senescence in cancer and aging. *Cell*. 130(2): 223-233.
- Cornish, S. M. and Chilibeck, P. D. 2009. Alpha-linolenic acid supplementation and resistance training in older adults. *Applied Physiology, Nutrition, and Metabolism*. 34(1): 49-59.
- Costa, A., Carrión, S., Puig-Pey, M., Juárez, F. and Clavé, P. 2019. Triple adaptation of the mediterranean diet: design of a meal plan for older people with oropharyngeal dysphagia based on home cooking. *Nutrients*. 11(2): 425. <https://www.mdpi.com/2072-6643/11/2/425>.
- Dar, B., Ahmed Dar, M. and Bashir, S. 2012. Calorie restriction the fountain of youth. *Food and Nutrition Sciences*. 3(11): 1522-1526. <https://doi.org/10.4236/fns.2012.311198>.

- Dhana, K., Koolhaas, C. M., van Rossum, E. F. C., Ikram, M. A., Hofman, A., Kavousi, M. and Franco, O. H. 2016. Metabolically healthy obesity and the risk of cardiovascular disease in the elderly population. *PloSone*. 11(4): e0154273.
- Dhyani, A., Chopra, R. and Garg, M. 2019. A review on nutritional value, functional properties and pharmacological application of *Perilla* (*Perilla Frutescens* L.). *Biomedical and Pharmacology Journal*. 12: 649-660. <https://doi.org/10.13005/bpj/1685>.
- dos Santos, M. A. Z., Alicieo, T. V. R., Pereira, C. M. P., Ramis-Ramos, G. and Mendonça, C. R. B. 2014. Profile of bioactive compounds in avocado pulp oil: influence of the drying processes and extraction methods. *Journal of the American Oil Chemists' Society*. 91(1): 19-27.
- Duarte, P. F., Chaves, M. A., Borges, C. D. and Mendonça, C. R. B. 2016. Avocado: characteristics, health benefits and uses. *Ciência Rural*. 46(4): 747-754.
- El-Sakka Ahmed, I. and Hassoba Howayda, M. 2006. Age related testosterone depletion in patients with erectile dysfunction. *Journal of Urology*. 176(6): 2589-2593. <https://doi.org/10.1016/j.juro.2006.08.005>
- Eriksson, M., Brown, W. T., Gordon, L. B., Glynn, M. W., Singer, J., Scott, L., Erdos, M. R., Robbins, C. M., Moses, T. Y. and Berglund, P. 2003. Recurrent de novo point mutations in lamin A cause Hutchinson–Gilford progeria syndrome. *Nature*. 423(6937): 293-298.
- Farooqui, T. and Farooqui, A. A. 2019. Chapter 14 - Potential therapeutic impacts of curcumin for improving memory impairment. In T. Farooqui & A. A. Farooqui (Eds.). *Curcumin for Neurological and Psychiatric Disorders*. pp. 257-273. Academic Press. <https://doi.org/10.1016/B978-0-12-815461-8.00014-1>.
- Farzaei, M. H., Bahramsoltani, R., Abbasabadi, Z., Braidly, N. and Nabavi, S. M. 2019. Role of green tea catechins in prevention of age-related cognitive decline: Pharmacological targets and clinical perspective. *Journal of Cellular Physiology*. 234(3): 2447-2459.
- Friedland, R. P. 2015. Mechanisms of molecular mimicry involving the microbiota in neurodegeneration. *Journal of Alzheimer's Disease*. 45: 349-362. <https://doi.org/10.3233/JAD-142841>.
- Fushimi, T., Fujihira, K., Takase, H. and Miyashita, M. 2023. Relationships among physical activity, physical function, and food intake in older Japanese adults living in urban areas: a cross-sectional study. *Geriatrics*. 8(2): 41. <https://www.mdpi.com/2308-3417/8/2/41>.
- Gao, M., Wu, B., Jin, W., Wei, J., Wang, J. and Li, J. 2022. Impact of aging on food consumption in rural China: Implications for dietary upgrading and health improvement. *Frontiers in Nutrition*. 9: 933343. <https://doi.org/10.3389/fnut.2022.933343>
- Garza, A. 2016. The aging population: The increasing effects on health care. *Pharmacy Times*. 82(1).

- Gomi, T., Kitayuguchi, J., Okuyama, K., Kamada, M., Inoue, S., Kamioka, H. and Mutoh, Y. 2022. Relationship between neighborhood food environment and diet variety in Japanese rural community-dwelling elderly: a cross-sectional study. *Journal of Epidemiology*. 32(6): 290-297.
<https://doi.org/10.2188/jea.JE20200415>.
- Grabowska, W., Sikora, E. and Bielak-Zmijewska, A. 2017. Sirtuins, a promising target in slowing down the ageing process. *Biogerontology*. 18(4): 447-476.
<https://doi.org/10.1007/s10522-017-9685-9>.
- Grochowicz, J., Fabisiak, A. and Ekielski, A. 2021. Importance of physical and functional properties of foods targeted to seniors. *Journal of Future Foods*. 1(2): 146-155. <https://doi.org/https://doi.org/10.1016/j.jfutfo.2022.01.004>
- Guarente, L. 2007. Sirtuins in aging and disease. *Cold Spring Harbor Symposia on Quantitative Biology*. 72: 483-488. <https://doi.org/10.1101/sqb.2007.72.024>
- He, W., Goodkind, D. and Kowal, P. R. 2016. An aging world: 2015. In: United States Census Bureau Washington, DC.
- Hunsakul, K., Laokuldilok, T., Sakdatorn, V., Klangpetch, W., Brennan, C. and Utama-ang, N. 2022. Optimization of enzymatic hydrolysis by alcalase and flavourzyme to enhance the antioxidant properties of jasmine rice bran protein hydrolysate. *Scientific Reports*. 12: 12582.
<https://doi.org/10.1038/s41598-022-16821-z>.
- Ide, K., Yamada, H., Takuma, N., Kawasaki, Y., Harada, S., Nakase, J., Ukawa, Y. and Sagesaka, Y. M. 2015. Effects of green tea consumption on cognitive dysfunction in an elderly population: a randomized placebo-controlled study. *Nutrition Journal*. 15(1): 49.
- Imai, S.-i. and Guarente, L. 2016. It takes two to tango: NAD⁺ and sirtuins in aging/longevity control. *NPJ Aging and Mechanisms of Disease*. 2(1): 16017.
<https://doi.org/10.1038/npjamd.2016.17>.
- Jackson, C. F. and Wenger, N. K. 2011. Cardiovascular disease in the elderly. *Revista Española de Cardiología (English Edition)*. 64(8): 697-712.
<https://doi.org/https://doi.org/10.1016/j.rec.2011.05.003>.
- Jackson, J. A., Branscum, A., Tang, A. and Smit, E. 2019. Food insecurity and physical functioning limitations among older U.S. adults. *Preventive Medicine Reports*. 14: 100829.
<https://doi.org/https://doi.org/10.1016/j.pmedr.2019.100829>.
- Kalra, E. K. 2003. Nutraceutical-definition and introduction. *Journal of the American Association of Pharmaceutical Scientists*. 5(3): 27-28.
- Khan, F., Ray, S., Craigie, A. M., Kennedy, G., Hill, A., Barton, K. L., Broughton, J. and Belch, J. J. F. 2014. Lowering of oxidative stress improves endothelial function in healthy subjects with habitually low intake of fruit and vegetables: A randomized controlled trial of antioxidant- and polyphenol-rich blackcurrant juice. *Free Radical Biology and Medicine*. 72: 232-237.
<https://doi.org/https://doi.org/10.1016/j.freeradbiomed.2014.04.006>
- Khan, H., Patel, S., & Majumdar, A. 2021. Role of NRF2 and Sirtuin activators in COVID-19. *Clinical Immunology*. 233: 108879.
<https://doi.org/https://doi.org/10.1016/j.clim.2021.108879>.

- Khan, N., Syed, D. N., Ahmad, N. and Mukhtar, H. 2013. Fisetin: a dietary antioxidant for health promotion. *Antioxidants & Redox Signaling*. 19(2): 151-162. <https://doi.org/10.1089/ars.2012.4901>.
- Kim, H., Kim, G., Jang, W., Kim, S. Y. and Chang, N. 2014. Association between intake of B vitamins and cognitive function in elderly Koreans with cognitive impairment. *Nutrition Journal*. 13(1): 118. <https://doi.org/10.1186/1475-2891-13-118>.
- Kökten, T., Hansmannel, F., Ndiaye, N. C., Heba, A. C., Quilliot, D., Dreumont, N., Arnone, D. and Peyrin-Biroulet, L. 2021. Calorie restriction as a new treatment of inflammatory diseases. *Advances in Nutrition*. 12(4): 1558-1570. <https://doi.org/10.1093/advances/nmaa179>.
- Kowluru, R. A., Zhong, Q., Santos, J. M., Thandampallayam, M., Putt, D. and Gierhart, D. L. 2014. Beneficial effects of the nutritional supplements on the development of diabetic retinopathy. *Nutrition & Metabolism*. 11(1): 8. <https://doi.org/10.1186/1743-7075-11-8>.
- Kukreja, A., Mishra, A. and Tiwari, A. 2013. Source, production and biological activities of piceatannol: a review. *International Journal of Pharmaceutical Sciences & Research*. 4(10): 3738-3745.
- Lee, B. J., Tseng, Y. F., Yen, C. H. and Lin, P. T. 2013. Effects of coenzyme Q10 supplementation (300 mg/day) on antioxidation and anti-inflammation in coronary artery disease patients during statins therapy: a randomized, placebo-controlled trial. *Nutrition Journal*. 12(1): 142. <https://doi.org/10.1186/1475-2891-12-142>
- Leung, M.-y., Chan Isabelle Yee, S. and Olomolaiye, P. 2013. Relationships between facility management, risks and health of elderly in care and attention homes. *Facilities*. 31(13-14): 659-680. <https://doi.org/10.1108/f-10-2011-0080>
- Li, S., Chen, G., Zhang, C., Wu, M., Wu, S. and Liu, Q. 2014. Research progress of natural antioxidants in foods for the treatment of diseases. *Food Science and Human Wellness*. 3(3): 110-116. <https://doi.org/10.1016/j.fshw.2014.11.002>
- Limtrakul, P., Semmarath, W. and Mapoung, S. 2019. Anthocyanins and proanthocyanidins in natural pigmented rice and their bioactivities. In *Phytochemicals in Human Health*. IntechOpen.
- Liu, C. B., Wang, R., Pan, H. B., Ding, Q. F. and Lu, F. B. 2013. Effect of lycopene on oxidative stress and behavioral deficits in rotenone induced model of Parkinson's disease. *Chinese Journal of Applied Physiology*. 29(4): 380-384.
- Lourenço, S. C., Moldão-Martins, M. and Alves, V. D. 2019. Antioxidants of natural plant origins: from sources to food industry applications. *Molecules*. 24(22): 4132. <https://doi.org/10.3390/molecules24224132>.
- Lutz, M., Petzold, G. and Albala, C. 2019. Considerations for the development of innovative foods to improve nutrition in older adults. *Nutrients*. 11(6): 1275. <https://doi.org/10.3390/nu11061275>.

- Lv, W., Du, N., Liu, Y., Fan, X., Wang, Y., Jia, X., Hou, X. and Wang, B. 2016. Low testosterone level and risk of alzheimer's disease in the elderly men: a systematic review and meta-analysis. *Molecular Neurobiology*. 53(4): 2679-2684. <https://doi.org/10.1007/s12035-015-9315-y>.
- Ma, Y., Yuan, Y., Bi, X., Zhang, L., Xing, Y. and Che, Z. 2019. Tenderization of yak meat by the combination of papain and high-pressure processing treatments. *Food and Bioprocess Technology*. 12(4): 681-693. <https://doi.org/10.1007/s11947-019-2245-3>.
- Maeda, K. and Akagi, J. 2016. Sarcopenia is an independent risk factor of dysphagia in hospitalized older people. *Geriatrics & Gerontology International*. 16(4): 515-521.
- Miean, K. H. and Mohamed, S. 2001. Flavonoid (myricetin, quercetin, kaempferol, luteolin, and apigenin) content of edible tropical plants. *Journal of Agricultural and Food Chemistry*. 49(6): 3106-3112. <https://doi.org/10.1021/jf000892m>.
- Min, J. and Min, K. 2014. Serum lycopene, lutein and zeaxanthin, and the risk of Alzheimer's disease mortality in older adults. *Dementia and Geriatric Cognitive Disorders*. 37(3-4): 246-256. <https://doi.org/10.1159/000356486>
- Min, S.-W., Sohn, P. D., Cho, S.-H., Swanson, R. A. and Gan, L. 2013. Sirtuins in neurodegenerative diseases: an update on potential mechanisms. *Frontiers in Aging Neuroscience*. 5: 53. <https://doi.org/10.3389/fnagi.2013.00053>
- Miyazawa, T., Abe, C., Burdeos, G. C., Matsumoto, A. and Toda, M. 2022. Food antioxidants and aging: theory, current evidence and perspectives. *Nutraceuticals*. 2(3): 181-204.
- Monzani, F., Pasqualetti, G., Caraccio, N. and Dell Agnello, U. 2016. Cognitive Function and the Ageing Process: The Peculiar Role of Mild Thyroid Failure. *Recent Patents on Endocrine, Metabolic & Immune Drug Discovery*. 10(1): 4-10. <https://doi.org/10.2174/1872214810666160701110509>.
- Morris, B. 2010. Calorie Restriction Mimetics and Aging. In book: *Calorie Restriction, Aging and Longevity*. pp. 141-175. https://doi.org/10.1007/978-90-481-8556-6_9.
- Murphy, M. P. and LeVine, H., 3rd. 2010. Alzheimer's disease and the amyloid-beta peptide. *Journal of Alzheimer's Disease*. 19(1): 311-323. <https://doi.org/10.3233/JAD-2010-1221>.
- Naderi, Z., Mozaffari-Khosravi, H., Dehghan, A., Nadjarzadeh, A. and Huseini, H. F. 2015. Effect of ginger powder supplementation on nitric oxide and C-reactive protein in elderly knee osteoarthritis patients: A 12-week double-blind randomized placebo-controlled clinical trial. *Journal of Traditional and Complementary Medicine*. 6(3): 199-203. <https://doi.org/10.1016/j.jtcme.2014.12.007>.
- Nakagawa, T. and Guarente, L. 2011. Sirtuins at a glance. *Journal of Cell Science*. 124(6): 833-838. <https://doi.org/10.1242/jcs.081067>.
- Ngampeerapong, C., Maneerat, N., Sitkongden, P., Saiyart, R. and Tangsuphoom, N. 2022. Formulation of reduced-sugar, fiber-enriched thai traditional sweet egg yolk cake 'Thong Ake'. *Food and Applied Bioscience Journal*. 10(1): 30-42.

- Nikolich-Zugich, J. 2012. The aging immune system: challenges for the 21st century. *Semin Immunol.* 24(5): 301-302. <https://doi.org/10.1016/j.smim.2012.09.001>.
- Nishimuro, H., Ohnishi, H., Sato, M., Ohnishi-Kameyama, M., Matsunaga, I., Naito, S., Ippoushi, K., Oike, H., Nagata, T., Akasaka, H., Saitoh, S., Shimamoto, K., and Kobori, M. 2015. Estimated daily intake and seasonal food sources of quercetin in Japan. *Nutrients.* 7(4): 2345-2358. <https://doi.org/10.3390/nu7042345>.
- Nishinari, K. and Fang, Y. 2018. Perception and measurement of food texture: Solid foods. *Journal of Texture Studies.* 49(2): 160-201. <https://doi.org/https://doi.org/10.1111/jtxs.12327>.
- O'sullivan, R. J. and Karlseder, J. 2010. Telomeres: protecting chromosomes against genome instability. *Nature Reviews Molecular cell biology.* 11(3): 171-181.
- Oliveira, B. F., Nogueira-Machado, J. A. and Chaves, M. M. 2010. The role of oxidative stress in the aging process. *The Scientific World Journal.* 10: 1121-1128. <https://doi.org/10.1100/tsw.2010.94>.
- Pakakaew, P., Phimolsiripol, Y., Taesuwan, S., Kumphune, S., Klangpetch, W. and Utama-ang, N. 2022. The shortest innovative process for enhancing the S-allylcysteine content and antioxidant activity of black and golden garlic. *Scientific Reports.* 12: 11493. <https://doi.org/10.1038/s41598-022-15635-3>
- Pannangrong, W., Wattanathorn, J., Muchimapura, S., Tiamkao, S. and Tong-un, T. 2011. Purple rice berry is neuroprotective and enhances cognition in a rat model of Alzheimer's disease. *Journal of Medicinal Food.* 14(7-8): 688-694. <https://doi.org/10.1089/jmf.2010.1312>.
- Pareek, S., Dixit, M., Govil, S., Jadhav, I., Shrivastava, D., Vahedi, M. and Bisen, P. S. 2019. Chapter 14 - Garlic and Its Role in Arthritis Management. In R. R. Watson & V. R. Preedy (Eds.). *Bioactive Food as Dietary Interventions for Arthritis and Related Inflammatory Diseases (Second Edition)*. Academic Press. pp. 245-252. <https://doi.org/https://doi.org/10.1016/B978-0-12-813820-5.00014-3>
- Passoni, C. R. M. S. and Coelho, C. A. R. 2008. Suplementação com ácido ascórbico tem efeito citoprotetor na cirrose biliar secundária: estudo experimental em ratos jovens. *Jornal de Pediatria.* 84: 522-528. http://www.scielo.br/scielo.php?script=sci_arttext&pid=S0021-75572008000700009&nrm=iso.
- Phaniendra, A., Jestadi, D. B. and Periyasamy, L. 2015. Free radicals: properties, sources, targets, and their implication in various diseases. *Indian Journal of Clinical Biochemistry.* 30(1): 11-26. <https://doi.org/10.1007/s12291-014-0446-0>.
- Poolsup, N., Suksomboon, N. and Paw, N. J. (2017). Effect of dragon fruit on glycemic control in prediabetes and type 2 diabetes: A systematic review and meta-analysis. *PloSone.* 12(9): e0184577.
- Poomipak, N., Samakradhamrongthai, R. S. and Utama-ang, N. 2018. Consumer survey of selected thai rice for elderly using focus group and acceptance test. *Food and Applied Bioscience Journal.* 6(Special): 134-143.

- Potter, G. A., Patterson, L. H., Wanogho, E., Perry, P. J., Butler, P. C., Ijaz, T., Ruparelia, K. C., Lamb, J. H., Farmer, P. B. and Stanley, L. A. 2002. The cancer preventative agent resveratrol is converted to the anticancer agent piceatannol by the cytochrome P450 enzyme CYP1B1. *British Journal of Cancer*. 86(5): 774-778.
- Poulose, N. and Raju, R. 2015. Sirtuin regulation in aging and injury. *Biochimica et Biophysica Acta (BBA) - Molecular Basis of Disease*. 1852(11): 2442-2455. <https://doi.org/https://doi.org/10.1016/j.bbadis.2015.08.017>.
- Quin, J., Engle, D., Litwiller, A., Peralta, E., Grasc, A., Boley, T. and Hazelrigg, S. 2005. Vitamin E succinate decreases lung cancer tumor growth in mice. *Journal of Surgical Research*. 127(2): 139-143. <https://doi.org/https://doi.org/10.1016/j.jss.2005.01.014>.
- Rahnasto-Rilla, M., Tyni, J., Huovinen, M., Jarho, E., Kulikowicz, T., Ravichandran, S., A. Bohr, V., Ferrucci, L., Lahtela-Kakkonen, M. and Moaddel, R. 2018. Natural polyphenols as sirtuin 6 modulators. *Scientific Reports*. 8(1): 4163. <https://doi.org/10.1038/s41598-018-22388-5>.
- Rodríguez-Rodero, S., Fernández-Morera, J. L., Menéndez-Torre, E., Calvanese, V., Fernández, A. F. and Fraga, M. F. 2011. Aging genetics and aging. *Aging and Disease*. 2(3): 186-195.
- Rouse, M. and Egan, J. M. 2018. Chapter 79 - Resveratrol in aging and age-related diseases. In J. L. Ram & P. M. Conn (Eds.), *Conn's Handbook of Models for Human Aging (Second Edition)*. Academic Press. pp. 1133-1142. <https://doi.org/https://doi.org/10.1016/B978-0-12-811353-0.00079-8>.
- Rusu, A., Randriambelonoro, M., Perrin, C., Valk, C., Álvarez, B. and Schwarze, A.-K. 2020. Aspects Influencing Food Intake and Approaches towards Personalising Nutrition in the Elderly. *Journal of Population Ageing*. 13(2): 239-256. <https://doi.org/10.1007/s12062-019-09259-1>.
- Sabaragamuwa, R., Perera, C. O. and Fedrizzi, B. 2018. *Centella asiatica* (Gotu kola) as a neuroprotectant and its potential role in healthy ageing. *Trends in Food science & Technology*. 79: 88-97.
- Saenjurn, C., Chaiyasut, C., Chansakaow, S., Suttajit, M. and Sirithunyalug, B. 2012. Antioxidant and anti-inflammatory activities of gamma-oryzanol rich extracts from Thai purple rice bran. *Journal of Medicinal Plants Research*. 6(6): 1070-1077.
- Saini, R. 2011. Coenzyme Q10: The essential nutrient. *Journal of Pharmacy and Bioallied Sciences*. 3(3): 466-467. <https://doi.org/10.4103/0975-7406.84471>.
- Saito, A., Imai, S., Htun, N. C., Okada, E., Yoshita, K., Yoshiike, N. and Takimoto, H. 2018. The trends in total energy, macronutrients and sodium intake among Japanese: findings from the 1995–2016 National Health and Nutrition Survey. *British Journal of Nutrition*. 120(4): 424-434. <https://doi.org/10.1017/S0007114518001162>.
- Salee, N., Chaiyana, W., Yawootti, A., Naruenartwongsakul, S., Klangpetch, W., Walter, P. and Utama-Ang, N. 2022. Optimization of the pulse electric field assisted extraction of black rice grain for antioxidant and sirtuin1 enzyme stimulation activities. *Scientific Reports*. 12(1): 6459. <https://doi.org/10.1038/s41598-022-10272-2>.

- Salminen, A., Kauppinen, A., Suuronen, T. and Kaarniranta, K. 2008. SIRT1 longevity factor suppresses NF- κ B -driven immune responses: regulation of aging via NF- κ B acetylation. *BioEssays*. 30(10): 939-942. <https://doi.org/https://doi.org/10.1002/bies.20799>.
- Samappito, J. 2021. Manufacture and properties of purple waxy corn yogurt and its application in probiotic salad dressing production. *Food and Applied Bioscience Journal*. 9(1): 11-27.
- Sanduzzi Zamparelli, M., Compare, D., Coccoli, P., Rocco, A., Nardone, O. M., Marrone, G., Gasbarrini, A., Grieco, A., Nardone, G. and Miele, L. 2016. The metabolic role of gut microbiota in the development of nonalcoholic fatty liver disease and cardiovascular disease. *International Journal of Molecular Sciences*. 17(8): 1225.
- Semwal, R., Semwal, D., Combrinck, S. and Viljoen, A. 2014. Butein: From ancient traditional remedy to modern nutraceutical. *Phytochemistry Letters*. 11: 188-201. <https://doi.org/10.1016/j.phytol.2014.12.014>.
- Sen, P., Shah, P. P., Nativio, R. and Berger, S. L. 2016. Epigenetic mechanisms of longevity and aging. *Cell*. 166(4): 822-839. <https://doi.org/10.1016/j.cell.2016.07.050>.
- Services, U. S. D. o. H. a. H. 2017. Dietary guidelines for Americans 2015-2020. Skyhorse Publishing Inc.
- Shah, K., Gleason, L. and Villareal, D. T. 2014. Vitamin K and bone health in older adults. *Journal of Nutrition in Gerontology and Geriatrics*. 33(1): 10-22. <https://doi.org/10.1080/21551197.2014.875818>.
- Shakti and Dubey, R. P. 2015. Ageing and anti ageing diet. *International Journal of Home Science*. 2: 25-27.
- Shamsizadeh, A., Roohbakhsh, A., Ayoobi, F. and Moghaddamhamadi, A. 2017. Chapter 25 - The role of natural products in the prevention and treatment of multiple sclerosis. In R. R. Watson & W. D. S. Killgore (Eds.). *Nutrition and Lifestyle in Neurological Autoimmune Diseases*. Academic. Press. pp. 249-260. <https://doi.org/https://doi.org/10.1016/B978-0-12-805298-3.00025-6>.
- Sing, S., Lee, H. H., Wong, S. C., Bong, C. and Yiu, P. H. 2015. Ferulic acid, gamma oryzanol and GABA content in whole grain rice and their variation with bran colour. *Emirates Journal of Food and Agriculture*. 27(9): 706-711. <https://doi.org/10.9755/ejfa.2015.04.067>.
- Singh, K., Srichairatanakool, S., Chewonarin, T., Brennan, C., Brennan, M., Klangpetch, W., & Utama-ang, N. 2022. Manipulation of the phenolic quality of assam green tea through thermal regulation and utilization of microwave and ultrasonic extraction techniques. *Horticulturae*. 8: 338. <https://doi.org/10.3390/horticulturae8040338>.
- Singh, K., Srichairatanakool, S., Chewonarin, T., Prommaban, A., Samakradhamrongthai, R., Brennan, M., Brennan, C. and Utama-ang, N. 2022. Impact of green extraction on curcuminoid content, antioxidant activities and anti-cancer efficiency (in vitro) from turmeric rhizomes (*Curcuma longa* L.). *Foods*. 11(22): 3633. <https://doi.org/10.3390/foods11223633>.

- Stanić, Z. 2017. Curcumin, a compound from natural sources, a true scientific challenge - a review. *Plant Foods for Human Nutrition*. 72(1): 1-12. <https://doi.org/10.1007/s11130-016-0590-1>.
- Stevens, J., Cai, J., Pamuk, E. R., Williamson, D. F., Thun, M. J. and Wood, J. L. 1998. The effect of age on the association between body-mass index and mortality. *New England Journal of Medicine*. 338(1): 1-7.
- Suantai, B., Jantakee, K., Kaewkod, T., Sangboonruang, S., Chitov, T. and Tragoolpua, Y. 2022. Anthocyanins in red jasmine rice (*Oryza sativa* L.) extracts and efficacy on inhibition of herpes simplex virus, free radicals and cancer cell. *Nutrients*. 14(9): 1905. <https://doi.org/10.3390/nu14091905>.
- Ter Borg, S., Verlaan, S., Mijnders, D. M., Schols, J. M. G. A., De Groot, L. C. and Luiking, Y. C. 2015. Macronutrient intake and inadequacies of community-dwelling older adults, a systematic review. *Annals of Nutrition and Metabolism*. 66(4): 242-255.
- Tomata, Y., Sugiyama, K., Kaiho, Y., Honkura, K., Watanabe, T., Zhang, S., Sugawara, Y. and Tsuji, I. 2016. Green tea consumption and the risk of incident dementia in elderly Japanese: the Ohsaki Cohort 2006 Study. *The American Journal of Geriatric Psychiatry*. 24(10): 881-889.
- Tripathi, K., Singh, Y., Dubey, S. and Selvan, T. 2016. Geriatric nutrition: need for better ageing. 2: 432-437. DOI:10.46370/sajfte.2016.v02i03and04.02.
- Vaiserman, A. M., Koliada, A. K. and Marotta, F. 2017. Gut microbiota: A player in aging and a target for anti-aging intervention. *Ageing Research Reviews*. 35: 36-45. <https://doi.org/https://doi.org/10.1016/j.arr.2017.01.001>.
- Villalba, J. M. and Alcáín, F. J. 2012. Sirtuin activators and inhibitors. *BioFactors* (Oxford, England). 38(5): 349-359. <https://doi.org/10.1002/biof.1032>.
- Weaver, C. M. (2013). Potassium and health. *Advances in Nutrition*. 4(3): 368S-377S.
- Willcox, B. J., Willcox, D. C., Todoriki, H., Fujiyoshi, A., Yano, K., He, Q., Curb, J. D. and Suzuki, M. 2007. Caloric restriction, the traditional Okinawan diet, and healthy aging: the diet of the world's longest-lived people and its potential impact on morbidity and life span. *Annals of the New York Academy of Sciences*. 1114(1): 434-455.
- Wyman, A. E. and Atamas, S. P. 2018. Sirtuins and accelerated aging in scleroderma. *Current Rheumatology Reports*. 20(4): 16-16. <https://doi.org/10.1007/s11926-018-0724-6>.
- Yokozawa, T. and Kim, Y. J. 2007. Piceatannol inhibits melanogenesis by its antioxidative actions. *Biological and Pharmaceutical Bulletin*. 30(11): 2007-2011.
- Yoshioka, K., Yamamoto, A., Matsushima, Y., Hachisuka, K. and Ikeuchi, Y. 2016. Effects of high pressure on the textural and sensory properties of minced fish meat gels for the dysphagia diet. *Food and Nutrition Sciences*. 7(9): 732-742. <https://doi.org/10.4236/fns.2016.79074>.
- Zhang, C.-F., Zhang, S.-L., He, X., Yang, X.-L., Wu, H.-T., Lin, B.-Q., Jiang, C.-P., Wang, J., Yu, C.-H., Yang, Z.-L., Wang, C.-Z., Li, P. and Yuan, C.-S. 2014. Antioxidant effects of Genkwa flos flavonoids on Freund's adjuvant-induced rheumatoid arthritis in rats. *Journal of Ethnopharmacology*. 153(3): 793-800. <https://doi.org/https://doi.org/10.1016/j.jep.2014.03.046>.

- Zhang, J., Wang, S. and Liu, B. 2023. New insights into the genetics and epigenetics of aging plasticity. *Genes*. 14(2): 329.
<https://www.mdpi.com/2073-4425/14/2/329>.
- Zhang, Z., Lowry, S. F., Guarente, L. and Haimovich, B. 2010. Roles of sirt1 in the acute and restorative phases following induction of inflammation. *Journal of Biological Chemistry*. 285(53): 41391-41401.
<https://doi.org/https://doi.org/10.1074/jbc.M110.174482>.