Mitigating Nutrition and Health Deficiencies in Older Adults: A Role for Food Innovation?

Sephora Baugreet, Ruth M. Hamill, Joseph P. Kerry, and Sinéad N. McCarthy

Abstract: The aim of this review is to describe the factors contributing to diminished food intake, resulting in nutritional deficiencies and associated health conditions in older adults and proposes food innovation strategies to mitigate these. Research has provided convincing evidence of a link between healthy eating patterns and healthy aging. There is a need to target new food product development (NPD) with functional health benefits specifically designed to address the particular food-related needs of older consumers. When developing foods for older adults, consideration should be given to the increased requirements for specific macro- and micronutrients, especially protein, calcium, vitamin D, and vitamin B. Changes in chemosensory acuity, chewing difficulties, and reduced or poor swallowing ability should also be considered. To compensate for the diminished appetite and reduced intake, foods should be energy dense, nutritionally adequate, and, most importantly, palatable, when targeting this cohort. This paper describes the potential of new food product development to facilitate dietary modification and address health deficiencies in older adults.

Keywords: age-related diseases, healthy aging, new product development (NPD), nutritional deficiencies

Practical Application: To describe health challenges associated with declining food intakes in older adults and identify how food innovation can assist with preserving functional ability and prolonging quality of healthy life.

Introduction

Aging population

Population aging is a significant and enduring global trend which, while positive in that more individuals are living longer, presents monumental societal challenges in terms of health, quality of life, and economic considerations. Global figures suggest that the proportion of adults aged over 60 y will increase from 12% to 27% by 2050 (WHO 2012; OECD 2013). The European population aged over 65 y will increase by an additional 20% by 2050 (European Commission 2015). Indeed, the concept of older age is increasingly complicated to define because old age is not uniform, that is, people have individual and varying experiences of each stage of aging that they encounter as they grow older. There appears to be a general trend toward defining older age as commencing at 65 y, although the rationale underpinning this cutoff is not clearly outlined. Commonly used variations of age classification are shown in Table 1. The World Health Organization (WHO) criterion, for example, sets the beginning of old age at 65 y, followed by the "early elderly" stage between 65 and 74 y, while a 75+ y is considered "late elderly." Each of these subgroups experiences specific issues and needs. Taking account of the changing demographic profile and the individual nature of the aging experience, the concept of "healthy aging," that is, maximizing the health outcomes at each stage of the aging process may be more important than establishing somewhat arbitrary age cutoff(s). Life expectancy has increased and now, living well for longer should be the goal, that is, society should strive to achieve lower levels of morbidity, fewer years of disability, and greater quality of life in the older population. Healthy aging can be described as leading a healthy, active, social, and independent life in later years, through maintaining vitality and good quality of life for as long as possible.

Nutrition is a key area where improvements are needed to bring tangible benefits to older people and enhance healthy aging of the population. This is because with aging comes an increased likelihood of developing chronic diseases, decreased functional ability, or cognitive decline and disability (Christensen and others 2009). For many of these age-related diseases, nutrition can play a role in modulating these conditions. While a number of chronic diseases are directly related to excess food intake such as obesity, type II diabetes, and hypertension, these challenges have been well documented elsewhere (Christensen and others 2009; Parekh and others 2011). In this paper, we will present the reasons for inadequate nutrient intakes as a result of factors associated with aging, such as impaired appetite, reduced food intake, and repetitive dietary choices and their consequences for weight, nutritional status, quality of life, and mortality risk. We will also present some positive food innovation options which may be used to increase food diversity and improved nutrient intake in older individuals, thereby enhancing nutritional status in older adults.

Specific nutritional needs of older adults

Aging adults are more susceptible to a decrease in body weight and loss of muscle mass, which in turn can increase frailty and morbidity. Thus, it is important that food products provide adequate nutrients in order to preserve and promote functional ability such as immunity, bone health, and cognitive function. Poor appetite may reduce food intakes resulting in difficulties achieving recommended intakes, especially for macronutrients such as protein and many micronutrients especially vitamin D, leading to reduced body weight and muscle mass. Good protein intake in the diet of older adults is essential to support healing, skin integrity,

JFDS-2016-1449 Submitted 9/5/2016, Accepted 1/31/2017. *Authors Baugreet and Hamill are with Food Quality and Sensory Science Dept., Teagasc Food Research Centre, Ashtown, Dublin, 15, Ireland. Authors Baugreet and Kerry are with Dept. of Food and Nutritional Sciences, Univ. College Cork, Cork, Ireland. Author McCarthy is with Dept. of Agrifood Business and Spatial Analysis, Teagasc Food Research Centre, Ashtown, Dublin 15, Ireland. Direct inquiries to author McCarthy (E-mail: Sinead.McCarthy@teagasc.ie).*

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Table 1–Overview of different studies providing the age criterion in defining old age.

Studies	Terms use to define "old" age	Age categories
(Orimo and others 2006)	Early elderly and late elderly	65 to 74-y old + 75-y old
(Reisenwitz and Iyer 2007)	Gray market (3rd generation)	+ 50-y old
(Meneely and others 2009)	Elderly	50, 55, or 60+ y
(Christensen and others 2009)	Young, old, 3rd age, oldest, old, and 4th age	65-y old + 85-y old
(Bleiel 2010)	Baby boomers	50-y old
(Kohijoki 2011)	Older or elderly	+ 65-y old
World Health Organization (WHO)	Early elderly and late elderly	65 to 74-y old 75+ y
(OECD 2015)	Elderly population	65+ y

immunity, and recovery from illness (Chernoff 2004). The current protein reference nutrient intake (RNI) is 0.8 g protein/kg body weight in healthy adults of all ages (Deutz and others 2014). While some authors (Bauer and others 2013; Pedersen and Cederholm 2014; Nowson and O'Connell 2015) recommend an increase in protein requirements, others (COMA 1991; Institute of Medicine 2005) suggest that this increase is not necessary because of the decrease in lean body mass and thus reduction in requirement for protein. Emerging evidence-based studies have argued that an increased protein intake may be beneficial to fulfill the needs of vulnerable older adults, particularly those with chronic diseases (Bauer and others 2013; Ziylan and others 2016). As well as an additional protein allowance, calcium (Ca) and vitamin D are recommended to prevent bone loss and maintain existing bone density, thereby reducing the risk of falls and fractures. A systematic literature review carried out by Lamberg-Allardt and others (2013) showed that the RNI for vitamin D intake is 20 μg per day for older adults with reduced capacity to synthesize vitamin D in the skin upon sun exposure. It is also important to note that while consuming intakes higher than the RNIs for vitamins A, B, E, Ca, and zinc are beneficial, no specific evidence is in place for vitamins C, K, and essential fatty acids (Marian and Sacks 2009). Recent research proposed that intakes above the RNI of certain nutrients, such as protein, vitamin D, and antioxidants, including carotenoids, vitamin E, and selenium, are associated consistently with beneficial effects on physical function and preventing chronic diseases in older age (Kaiser and others 2010).

Decline in dietary intake and quality in older people

Dietary intake and adequate nutrition in older age have a significant role in the health and well-being of older adults. In this population subgroup, energy expenditure frequently exceeds energy intake, thereby leading to weight loss, muscle wasting, and increased weakness. Consequently, this results in a decrease in muscle mass and metabolic rate, thus impacting on appetite, physical activity, ability to carry out daily functions (functional ability), and health status. As noted by Robinson and others (2012a), food consumption can decline by as much as 25% in adults aged 70 y and older. Additionally, in extreme cases, daily energy intake below 1000 kcal per day has been reported among free-living older adults aged 70+ (Morley and Thomas 2007). Data on dietary intake in the institutional setting showed inadequate energy intake among 60% of older adults, while up to 70% had both low energy and micronutrient intakes when vitamins B, E, magnesium, and zinc were included (Kaiser and others 2010).

Reasons for poor food choice in older adults

Physical impairments such as reduced mobility, limited access to shops in order to purchase, prepare, and consume foods, as well as other social and medical reasons are factors that affect food choices in older adults (Brownie 2006). The price of nutritious foods can also impact upon food consumption in free-living older individuals. Older adults in institutions often experience low food intake as a result of isolation, dental problems, depression, or chronic illnesses. The proportion of malnourished adults in this setting was shown to be as high as 60% (Woods and others 2009). A large-scale Belgian study assessing nutritional status among older adults aged between 75 and 85 y identified 71% with swallowing difficulties and 57% with taste loss, which was strongly associated with being malnourished (Vanderwee and others 2010). Chemosensory acuity and difficulty in chewing and swallowing foods contribute to poor nutritional status and reduced appetite. Older adults are more concerned about food texture (Forde and Delahunty 2004), compared to younger adults, as they commonly have difficulty consuming hard, crunchy, dry, and stringy textured foods, such as meat products and celery (Hildebrandt and others 1997). Therefore, their intake of important protein and micronutrient sources, such as red meat, can decline. Alzheimer's patients can experience sensory losses and decreases in gustatory and olfactory acuities, which may be responsible for a lack of interest in food consumption. Many chronic diseases, as well as inadequate availability of visually appealing, high-quality food, can have adverse effects on appetite. Furthermore, medications frequently prescribed for older adults may cause unpleasant side-effects such as drowsiness, forgetfulness, nausea, and altered taste perception (Evans 2005), as well as having impact on the digestive tract and consequently, on dietary intake. Along with these challenges, older adults have smaller appetites and consume smaller portions of food, so it becomes even more challenging for them to meet their nutritional requirements, especially for micronutrients. Early satiety onset and physiological appetite loss are common experiences among older adults and contribute to diminished food intake. Physiological and social factors outlined in Table 2 have been shown to influence dietary intake in older adults.

Specific nutritional deficiencies in older people

The link between adequate nutrient intake, both for macro- and micronutrients, and healthy aging is increasingly supported by the scientific literature (Ferry and Roussel 2011; Dangour and others 2012; Beasley and others 2013). A lack of variety in food consumed and reduced consumption levels have an impact on the body's ability to digest food since these factors ultimately slow the process of absorption, transportation, metabolism, and result in an inadequate supply and storage of nutrients in the body (Deierlein and others 2014). Low food intake in older adults results in inadequate intake of energy, protein, and many micronutrients, thereby leading to cases of reported malnutrition (Hebuterne and others 2001; Hickson 2006). The British Association for Parental and Enteral Nutrition (BAPEN) published a definition for the term "malnutrition," which refers to a lack, excess, or imbalance in an individual requirement for energy, protein, and other nutrients in which a deficiency would alter body composition and function (BAPEN 2016). Table 2 summarizes the risk factors contributing to an increased risk of developing nutritional deficiencies in older adults. Specific nutritional deficiencies linked to vitamins B, C,

Table 2–Risk factors contributing to the development of nutritional deficiency in older adults.

Cause of nutritional deficiency	Consequence
Physical and physiological[a]	
Changes in body composition	Reduced metabolic rate and loss of muscle mass
Altered nutrient requirements	Insufficient energy and nutrients intake
Decreased physical activity	Progressive loss of body weight and reduced appetite
Sensory impairment[b]	
Decreased sense of taste and smell	Reduced appetite
Loss of vision and hearing	Decreased ability to purchase and prepare food
Dental problems	Difficulty in chewing and poor-quality diet
Age-related issues	
Dementia	Decreased ability for self-care and increased morbidity
Sarcopenia	Decreased functional ability, assistance needed with activities of daily living (ADLs), and increased frailty
Social determinants	
Financial restraints and poverty	Poor diet and limited access to food
Social isolation, reduced mobility, and lack of transport	Inappropriate food choices
Widowhood and bereavement	Food aversion
Decrease independence	Decreased food intake and inability to self-feed

Cumulative effect → progressive undernutrition[c]
Source: (Brownie 2006[a]; Talwar and Malik 2013[b]; Vlachos and others 2013[c]).

D, E, and K and trace elements: zinc, iron, potassium, and selenium have been reported for older institutionalized adults (Alles and others 2012; Shatenstein and others 2013; Torbergsen and others 2014). A study on European population groups (64+ y) indicated that 11% had intakes below the RNI for at least one of the following nutrients: zinc, vitamins B_{12}, and C, while 21% had intakes of vitamin D, folic acid, Ca, selenium, and iodine below the RNI's (Roman Vinas and others 2011). Similar findings from the Survey in Europe on Nutrition and the Elderly, a Concerted Action (SENECA) project reported that there was insufficient intake of one or more nutrients in 24% of European older men and 47% of European older women (de Groot and others 1999). Furthermore, the National Diet and Nutrition Survey reported nutritional deficiency in individuals aged 65 y and over in the U.K. for both free-living and institutionalized persons. Folate deficiency was also identified among 29% and 35% of free-living and institutional-cared older people, respectively (Saunders and Smith 2010). Dietary data collected from a large national survey in the U.K. found vitamin D intakes below the RNI for 97% and 99% of older adults over 65 y in free-living and institutionalized settings, respectively (Buttriss 2000).

Age- and nutritional-related conditions

Inadequate food intake contributes to many health conditions including malnutrition, sarcopenia, osteoporosis, and cognitive decline. Prevention and mitigation strategies are possible and nutritional strategies are needed to enhance consumption of the foods that may prevent or delay the onset of these conditions and promote healthy aging.

Sarcopenia

Sarcopenia is the progressive depletion of muscle mass and loss in strength, which is associated with a consequent risk of adverse outcomes; poor functional status and an increased risk of chronic diseases (Cruz-Jentoft and others 2010). It is a highly prevalent condition among aging individuals (Gariballa and Alessa 2013) and also occurs in those who are immobile, even in the absence of comorbidities. Hence, it represents a serious global health challenge. The prevalence of sarcopenia varies across the world, ranging from 3% to 33%, as reported by Cerri and others (2015). A decline of 1% to 2% of muscle mass is reported in individuals aged 50 y+ and increases to approximately 50% among those aged over 80+ y (Young and others 2013). Inactivity is a major contributor to sarcopenia and muscle loss as a consequence of an imbalance between synthesis and degradation of muscle proteins (Paddon-Jones 2006). In many older adults, the cause of sarcopenia is multifactorial, but it is primarily influenced by the aging process. Low intakes or deficiencies in energy, protein, and vitamin D, in addition to acute or chronic diseases may also exacerbate the development of sarcopenia. A poor protein intake results in a decrease in lean muscle mass, limiting muscle protein synthesis and increasing oxidative damage of muscle tissue (Volkert 2011). In addition, deficiencies in vitamins B, D, and some antioxidant nutrients, that is, carotenoids, selenium, vitamins C, and E are also implicated in the development of sacropenia as outlined in Table 3. Amino acids are also essential nutrients required for the stimulation of muscle protein synthesis (Katsanos and others 2006). Leucine, in particular is recognized to have a role in the synthesis of muscle protein and the management of sarcopenia (Robinson and others 2012a). More attention should be paid to diets providing adequate energy and nutrients to ensure sufficient intake and coupled with physical activity to prevent or postpone the onset of sarcopenia. Diet and daily self-care activities such as cooking, eating, and access to food to ensure independent living collectively contribute to quality of life which can have a significant impact in preventing sarcopenia (van het Bolscher-Niehuis and others 2016).

Osteoporosis

Osteoporosis is prevalent among older adults. It is a systemic skeletal disease portrayed by low bone mass and structural weakening of bone tissue that leads to reduced bone strength and increased susceptibility to fracture. It is frequently referred to as a "silent disease" (Caroli and others 2011). It may occur as a result of the aging process or it may arise from different chronic diseases, from effects of medications and from nutritional deficiencies, all of which significantly contribute to bone mineral loss. With a low or reduced bone density, the risk of fractures of the hip, wrist, and vertebrae increases with age. Women are predominantly affected due to hormonal changes that occur at menopause, resulting in the rapid loss of bone mass (Hernlund and others 2013), but it also affects a significant number of men worldwide. In 2010, it was estimated that 22 million women and 5.5 million men (50 to 84 y) already had osteoporosis (Euromonitor 2013). By 2050, the prevalence of this condition is anticipated to rise in conjunction with the increasing proportion of older adults, if new approaches are not found or used to tackle this issue. Fortunately, osteoporosis is largely preventable by improving lifestyle factors, especially nutrition and exercise. It has been shown that diet and exercise work in combination whereby optimal nutrition is required to achieve the optimal benefit from exercise (Mithal and others 2013).

Vitamin D and Ca are well supported in terms of their contribution to bone health and the prevention or mitigation of this

Table 3–Age-related conditions and their associative nutritional deficiency.

		Malnutrition	Cognitive function	Sarcopenia	Osteoporosis
Macronutrients	*Protein*	√		√	√
	Carbohydrate	√			√
	Lipids	√		√	√
Micronutrients					
Water-soluble vitamins	B_6	√	√	√	√
	B_9 *(Folate)*	√	√	√	√
	B_{12}	√	√	√	√
	C	√	√	√	√
Fat-soluble vitamins	*A*	√		√	
	D			√	√
	E	√	√		
	K	√			√
Minerals	*Calcium*	√			√
	Magnesium				√
	Phosphorous				√
	Potassium				
	Iron	√			
	Zinc	√			√
	Selenium	√			√
Other nutrients	*β-Carotene*		√		
	Carotenoids			√	

disease. Older adults (65+y) in Europe are recommended to achieve a Ca intake of 700 to 800 mg/d (Gennari 2001). However, many older people in institutions fail to consume this recommended level (Lau and others 2001). In order to avoid osteoporosis in later life, achieving maximum bone density at a young age (children and adolescents) is crucial. This is because healthy young adults generally reach their peak bone mineral content by 20 y of age (Bonjour 2001). A 10% increase in bone mineral content may reduce the risk of osteoporotic fractures by 50% throughout adult life (Bonjour 2001). Vitamin D is considered an essential nutrient in bone health and calcium homeostasis (Artaza-Artabe and others 2016). With an increasing age, several factors affect the ability to synthesize vitamin D; such as aging of the skin, limited sun exposure, less varied diet, and changes in lifestyle. Insufficient consumption of foods rich in vitamin D, for example, fish or fortified products, contributes to low vitamin D status in older adults (Gennari 2001). The vitamin D status of the European population is highly variable. In a Danish population-based study, 80% of older adults aged 65+ were at high risk of vitamin D deficiency (Leif 2005). These figures are also in accordance with Lips (2007), who reported a prevalence of up to 80% in older institutionalized adults, while a deficiency of 2% to 30% among adults in Europe was observed. A large body of research indicates that an adequate intake of Ca and vitamin D over lifetime will slow progressive bone loss (Larsen and others 2004; Ohta and others 2016).

Cognitive decline and dementia

Cognitive decline can develop gradually with age in many people. The progression of cognitive decline begins during early adulthood and the impact of diet on older age cognition is likely to be a function of nutritional intake over a lifetime. The stages of cognitive decline range from normal age-associated changes, through to mild cognitive impairment (MCI) and, at its most severe, to dementia (Lipnicki and others 2013). MCI in older adults is described as the loss of memory, but does not affect daily functional status (Park and others 2003). However, Alzheimer's disease (AD) is the most common cause of dementia in older people and has a significant impact on daily functional status. According to Wimo and Prince (2010), the prevalence of dementia in the European Union is 14% for men and 16% for women (aged 80 to 84 y) and increases up to 31% and 47%, respectively, in individuals aged 90 y and over. Good nutrition is important for optimal brain function throughout the life-cycle (Dauncey 2009). More frequent vegetable consumption was found to be beneficial in protecting against cognitive decline in a cohort of >65 y-old participants (Trichopoulou and others 2014). Similarly, consumption patterns comprising of grains, fruits, and vegetables among adults aged 40 y and older (Kesse-Guyot and others 2011) and a diet rich in fruits, vegetables, fish, monounsaturated fatty acids (MUFA), and polyunsaturated fatty acids (PUFA) have been reported to prevent cognitive decline and lower the risk of dementia and associated mortality (Alles and others 2012; Morris 2012; Caracciolo and others 2014; Ogawa 2014). The maintenance of healthy neurons for cognitive function relies on an adequate supply of specific nutrients, as outlined in Table 3. B vitamin is required for the formation of red blood cells and the maintenance of a healthy nervous system. A deficiency in B vitamin such as folic acid, cyanocobalamine, and pyridoxine has been associated with poor cognitive function (Murakami and others 2010). An intervention study carried out by Durga and others (2007), which supplemented B vitamin in participants aged 50 to 70-y old, demonstrated significant improvements in cognitive function. Kennedy and others (2011) reviewed epidemiological studies showing the link between macro- and micronutrients and cognitive function. The majority focused on the older cohort that was already at risk or suffering from cognitive decline, specifically focusing on B vitamin. This study concluded that the need for nutrients, most notably B vitamin, should start at an earlier stage to ensure adequate intake and maintain healthy cognitive function. Other dietary antioxidants such as β-carotene and vitamins C and E play a protective role against cognitive decline by reducing the negative effects of free radicals (Barberger-Gateau and others 2007). The presence of free radicals in the brain contributes to the development of age-related cognitive impairments.

Table 4–Factors to be considered when developing new products for older adults.

Factors	Implication
Sensory aspects and nutrition	Optimize taste, mouthfeel by the use of intense or concentrated flavor ingredients; optimize texture, that is, between soft and semihard; nutritional optimization, that is, macro- and micronutrients fortification; and improve food palatability and acceptance
Affordability	Convenience, freedom of choice, accessibility to shop, and cost of food
Product format and packaging	Accessible packaging, that is, easy-to-open, easy-peel, and open tear tabs; type of product: refrigerated, frozen, or shelf stable, that is, single-serve, multicompartment container; improved opening mechanism, that is, resealable packages or with good grip; improved usability, that is, lighter pack for ease of handling; and legibility of labels, that is, font size, contrasting colors, and clearer diagrams

Source: (Kohijoki and Marjanen 2013; Takeuchi and others 2014).

A recent trial examining adults aged >70 y with MCI found that a high dose of folic acid (0.8 mg), vitamin B_{12} (0.5 mg), and B_6 (20 mg) supplementation for 24 mo was associated with a slower cognitive decline in those receiving the intervention, compared to those receiving the placebo (de Jager and others 2012). These are the same nutrients that are to be found in the high fruit and vegetable diet described by Trichopoulou and others (2014) to be associated with a reduction in cognitive decline. These findings confirm that nutrient supplementation plays a very important role in reducing the rate of cognitive decline (Barberger-Gateau and others 2007; de Jager and others 2012; Otaegui-Arrazola and others 2014) and in the promotion of healthy brain aging.

The way forward: new product considerations for older consumers

Based on the research reviewed and the wealth of evidence supporting the role of nutrients in the aging process, future approaches in new food product development should focus on developing novel means to address the specific nutritional requirements of the older adult, while accounting for decrease in olfactory function, change in sensory food perception, and preferences in this group. This presents a significant challenge for food production.

Hence, in this paper, we wish to describe potential avenues toward the development of nutritionally balanced products that could assist the older cohort to maintain an active and healthier aging process. It is essential to tailor nutrient dense foods that meet their specific nutritional requirements, which are easily accessible, appealing, and with appropriate sensorial attributes (appearance, presentation, size, color, flavor, texture, and consistency) that would be traditionally and frequently consumed (den Uijl and others 2016). It is essential that foods designed for older people address nutritional deficiency, functional ability, improve liking, and ultimately consumption taking into account other confounding factors such as variation in sensory perception, realistic consumption settings, for example, home or nursing home as well as prevailing health conditions. Various factors such as chemosensory appeal, packaging solutions, and micronutrient enhancement as outlined in Table 4 should be considered during the new product development (NPD) process.

The challenge of chemosensory appeal for foods for the older cohort

Over the last 10 to 15 y, a significant body of research has emphasized that changes in chemosensory function impact on food intake in older adults. Older adults are challenged by a loss in chemosensory acuity, generally more pronounced in adults >70 y of age (den Uijl and others 2016; Giacalone and others 2016). Various factors, for example, age-related diseases and medications, were found to alter food preferences and intake (Giacalone and others 2016). These findings were also replicated in malnourished older adults in institutionalized settings (Methven and others 2016). Additionally, diminished sensorial function, less varied food choices, and reduced preferences may be largely influenced by habit, tradition, mobility, and social environment. Characteristics of the food itself such as packaging, food consistency, temperature, and visual appeal as well as motives for food choice such as cost and convenience also play an important role in food choice. The relationship between aging and taste perception has been previously well documented (Methven and others 2012), and the general consensus identified that taste detection thresholds increased simultaneously with age (Schiffman and Warwick 1993; Schiffman 2000; Mattes 2002); consequently, such issues are considered to impact on appetite and food intake among older adults (Griep and others 2000; Best and Appleton 2011). Older adults experience an elevated sensorial threshold, when a greater concentration of the stimulus is required before it can be sensed (Schiffman 1993). Detection thresholds in older adults for basic taste, for example, sweeteners, salt, acids, and bitter compounds, were 4 to 5 times higher than in comparison to younger adults (Schiffman 1993). This reduction in their ability to detect flavors in food may lead to a bland food experience and to a move toward foods with more intense flavors, for example, those containing higher levels of sugar or salt, which may be less healthy, to compensate for their perceptual impairment. Goeminne and others (2012) showed increased food appreciation among participants receiving meals on wheels in terms of food quality and choice. Kim and others (2010) found that preference for a salty taste in healthy older adults increased their food intake.

Nevertheless, it is worthwhile to mention that the literature is conflicting in this area and some studies showed that loss of taste sensitivity in older adults did not necessarily lead to a preference for flavor-enhanced foods (Mojet and others 2005; Doets and Kremer 2016). However, Methven and others (2016) reviewed several studies looking at the sensory quality and quality of life for the older population, and concluded that a gap still remains to gauge sensory perception and preferences in older adults.

Strategies have been identified to address chemosensory decline in older adults. These include flavor and taste enhancements of meat, dairy, and bakery products that may amplify taste sensations and consequently stimulate appetite. Such enhancement may compensate for perceptual losses, improve food intake, palatability, and acceptance. Griep and others (2000) showed that flavor amplification in a meat substitute (Quorn) and yoghurt influenced food preferences with an increase in intake of these intensely flavored products among older adults. Several authors demonstrated that additives such as monosodium glutamate (Schiffman 2000) or artificial flavorings such as roast beef, bacon, or cheese, fruits such as citrus or pomegranate byproducts, and spices such as rosemary, garlic, paprika, and onion (Smith and others 2008; Best and Appleton 2011) may increase intake. Best and Appleton (2011) demonstrated increased liking and improved energy, protein, and

fat intakes among older adults following the addition of *Bisto* chicken or onion gravy to their meal. Similarly, Schiffman (1998) reported a calorie increase of 10% in flavor-enhanced meals for hospitalized patients. A study designed to encourage food consumption in older AD patients investigated the impact of shape, contrast, and sauce on consumption of finger foods and found higher consumption of finger foods with sauce and contrast, for example, 2 layers, rather than foods where all of the ingredients were mixed together (Pouyet and others 2014). Some reports found that enhancing chemosensory appeal increases acceptability and preferences for specific foods consequently improving nutritional status in older adults (Schiffman 1993; Schiffman 2000; Best and Appleton 2011).

Poor chewing ability due to decreased muscular strength, dental problems, and swallowing difficulties can affect consumption of important staple foods, for example, meats, fruits, vegetables, pasta, and bakery produce. The perceived hardness and chewiness, requiring increased chewing effort and fatigue associated with the consumption of these staple foods among older adults are often reduced. Textural perception, for example, creaminess, smoothness, crunchiness, crispness, and elasticity are important attributes in determining overall acceptance of food (Doets and Kremer 2016). Roininen and others (2003) showed that older adults preferred foods that can be consumed effortlessly providing an easy eating experience, while it is important to note that at the same time, textures that were too smooth or too soft were not appreciated. Another study by Kälviäinen and others (2002) found that texture manipulations of muesli oat flakes were more appreciated among older people than their younger counterparts. Tuorila and others (1998) described a higher intake in older Finnish adults consuming oat bran pudding with texture manipulated to mimic flavored yoghurt. These findings are in accordance with approaches identified by Peleg (1993), such as maintaining crunchiness in the development of products with textures requiring reduced mastication effort which may be more suited to the older cohort. Textural properties can be enhanced by the addition of functional ingredients such as fibers, oats, and even bamboo. Manipulating textural characteristics would be advantageous in terms of improving food properties and reducing mastication effort, while at the same time ensuring that flavors are naturally released to increase the consumption in older adults.

Packaging solutions

In the U.K., more than 60000 packaging-related injuries such as cuts, bruises, and even severed fingers have been reported each year by the National Health Service with a higher prevalence among older adults with reduced hand strength, poor eyesight, and disability (Britten 2015). The gradual loss of strength in the hand and wrists associated with old age, especially those over 80 y (Yoxall and others 2010), causes difficulties in terms of open-ability and accessibility of food products. Poorer eyesight in older adults presents difficulties in reading the fine print on labels; hence, instructions regarding cooking, handling, holding, and perishability are frequently neglected, endangering health. As a result of a decline in functional ability, such difficulties can increase the risk of malnutrition and food poisoning; decline in general health, as well as injuries, that is, burns (Galley and others 2015). The British Standards Institution (BSI) found that nearly half of the over 65s surveyed reported difficulty in opening daily items such as bottles, jars, plastic packs, and tins (BSI 2011). Redesigning packaging for the aging population could offer convenience and easier accessibility to food products. Recent innovations in packaging solutions beneficial to this cohort already exist on the market, for example, paper wrapper which are "easy-to-tear" and retain freshness, self-venting and easy-peel packaging for hot-serve products to avoid burns, orbit lid on jars that facilitate one-directional opening, and vacuum skin packaging technology that enables products to be cooked, transported, reheated, and served all in one package (Weber 2014). Additional communication innovations such as braille, raised logos, contrasting colors, or clearer diagrams are used for the easy identification of foods on the market. More recently, sound speech instructions incorporated into the packaging to remind older adults to take medicines, eat, or simply providing warnings, for example, allergies, are also emerging. Additionally, older adults tend to consume smaller portions (Hall and others 2003), therefore it would be equally important to incorporate single portions or smaller pack sizes with resealable features.

Future strategies

This review outlines a definite need for the development of foods and beverages to promote healthy food consumption and thus healthy aging among older adults. Recently, demands for more suitable and acceptable food products, taking into account sensory characteristics (appearance, taste, flavor, texture, and consistency) as well as health benefits, convenience, and packaging to promote healthy aging, are urgently needed. More research into developing improved combinations of flavors in widely consumed nutrient dense products such as meat, cereal, and dairy remains to be investigated further. Another approach could include incorporating natural ingredients rich in umami taste or intense flavor ingredients, that is, tomatoes, sharp-aged cheese, shiitake mushrooms, soy and garlic, onion, concentrated fruit sauce or flavored oils/vinegars, or spices with bolder aromas, that is, basil, chives, coriander, and sage rosemary. Other factors that could significantly help increase appeal and satisfaction among older adults are innovative packaging solutions and on-pack communications (Den Uijl and others 2016). Some of these include high visibility badges communicating information such as low salt, low sugar, and 100% natural as well as trusted seals, that is, gluten free or halal certified or sound speech instructions to the consumer (Connolly 2015). These considerations should be included at the early stage of the NPD process. Consequently, the result will be an increase in dietary intake (macronutrients and micronutrients) of high-quality foods thus preventing or reducing the risk of age-related diseases such as sarcopenia, osteoporosis, and cognitive decline.

Conclusion

Inadequate macro- and micronutrient intakes are common among older people. As demonstrated in many studies, this contributes to weight loss, malnutrition, and associated conditions such as sarcopenia and cognitive decline. Indeed, age-related conditions are increasing in prevalence with the increase in the aging population worldwide. Chemosensory acuity is negatively affected by factors (medication and dentures) associated with the aging process and this has been shown subsequently to lead to negative changes in food preferences/appreciation and diet. By considering nutritional gaps and challenges, potential high-quality food products can be tailored specifically to enhance nutritional status and health of older adults. This can be achieved by fortifying foods with selected functional ingredients, vitamins and minerals which may offer additional potential to enhance the nutritive value of individual portions of food. By also providing products

with beneficial attributes such as ready-to-eat, easy-to-open, and easy-to-bite and chew will help fulfill this cohort's nutritional and functional needs. This relatively unexplored area of NPD should lead to new innovative food products, incorporating key nutrients in improved packaging formats to help moderate the diet- and age-related health conditions.

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Author Contributions

Sephora Baugreet devised, drafted, and revised the manuscript under the supervision of Sinéad N. McCarthy, Ruth M. Hamill, and Joseph P. Kerry and Sinéad N. McCarthy contributed to the revisions and gave final approval of the version to be submitted.

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