

Sensory impairment as a natural result of aging & potential product development strategies

by

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## **Abstract**

Over the next 10 years, a generational group known as the Baby Boomers will become America's senior citizens and account for 22% of the country's population but this demographic is generally overlooked. This demographic largely wants to maintain a good quality of life and age in a healthy manner, but aging comes with many challenges that may shade their experiences. Sensory impairment is one of these challenges that changes their experience of food products and may cause some older adults to develop eating habits that may not align with developing medical conditions. This review addresses prevalence and severity of impairment for each of the five senses and the role of texture as humans age, such as the decline of olfactory acuity and the increase in basic taste thresholds.

Despite the heterogenous impact of sensory impairment on older adults and the alterations to sensory perception of foods, it is not associated with reduced food liking. Consumers' opinions of foods and their choice of foods are based on a variety of information beyond sensory attributes of products. It is the complex combination of expectations, context as well as the sensory attributes perceived. The food industry can implement a combination of intrinsic and extrinsic strategies to help older adults overcome age-related sensory decline to make food choices that promote healthy aging. Additional research should focus on the influence on context, such as health claims and eating situations, and understanding food textures that benefit older adults with poor dental health. Food products should be evaluated holistically, from packaging to last bite, to better guide and encourage food purchase, consumption, and liking towards healthy aging among older adults.

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## **Dedication**

To my parents, the seniors in my life, who raised me to value and pursue academic and professional excellence and provided me with the opportunities to expand my horizon. This path may not have been exactly what you wanted, but I achieved the goals you hoped I would. I hope and wish that you both maintain your health and age gracefully for years to come.

## **Chapter 1 -**

# **Sensory Impairment as a Natural Result of Aging & Potential Product Development Strategies**

### **1. Introduction**

Globally, senior citizens are defined as adults over the age of 65. In the U.S., this demographic is increasing as the generational group known as the Baby Boomers age. Baby Boomers are defined as adults born between 1946 and 1964. Over the next 10 years, all Baby Boomers will be senior citizens. In Mintel's 2019 report on Marketing to Baby Boomers, it was stated that Americans over the age of 50 have a median net worth that is nearly twice as much as Americans between the age of 18 and 49. This generational group accounts for 22% of the U.S. population whereas the Millennial group accounts for 24% of the U.S. population (Mintel, 2019). Baby Boomers are largely overlooked despite their wealth and comparable size to millennials. As reported by the international communication organization Havas, roughly 5% of U.S. advertising targets consumers over the age of 50 (Mintel, 2019). Baby boomers should not be overlooked. This aging group has needs and wants that should be addressed to maintain a good quality of life and support healthy aging.

There are several challenges that come with aging. The main concern for most is overall health and maintaining it. Though most boomers do not consider themselves "seniors" nor "dependent," it is not uncommon that they are experiencing the effects of aging or have seen the effects on their parents or peers. This could lead to fears of losing their independence, fears of being a burden, and so on. From a medical perspective, frailty and sarcopenia are two of many chronic conditions that impact seniors. Frailty is a multisystem disorder observed in the elderly,

which includes the decline in mental and physical abilities (Clegg et al., 2013). Sarcopenia is the decline in skeletal muscle mass associated with aging which contributes to frailty (Marty et al., 2017). Both conditions increase the risk of mortality. With frailty and sarcopenia, individuals are more likely to suffer from accidental falls or other injuries that may result in decreased physical mobility, loss of self-confidence, and diminished quality of life (Esquivel, 2017). A key predictor of these conditions and overall quality of life is the nutritional status of the individuals (Artaza-Artabe et al., 2016; Esquivel, 2017). Unfortunately, appetite loss in older citizens or the anorexia of ageing is common (Cox et al. 2020). This appetite loss occurs regardless of medical condition. The reduction of appetite occurs due to age-related changes of three main factors: physiological signaling, hedonism, and external cues (Cox et al., 2020). There is an opportunity for the food industry to address the hedonics and some external factors of food to overcome appetite loss, improve the nutritional status of elders, and promote healthy aging.

Baby Boomers already have a large focus on health and wellness to sustain their quality of life (Intel, 2019). They want to maintain control and ownership over their own health and are looking for food solutions that can provide health benefits (Intel, 2019). Before the food industry can provide these solutions, it is important to understand the consumer and the current marketplace. Older adults experience some form of sensory impairment, but not all experience the same sensory impairments nor same degree of impairment. It is individualized based on the consumers' age, sex, nutritional status, medical history, work history, education and social-economic status. Since the health status of older adults varies, this review will focus on independent consumers who are not in long-term care facilities or hospitalized. This paper will cover the impact of aging on the senses, potential solutions to sensory impairment, external factors that influence food choice, and what the current market for senior citizens looks like.

## **2. Changes in Sensory Perception of Food**

It is commonly held that with old age comes some form of sensory decline, whether that be sight, hearing, smell, taste, or touch. In 2018, Cavazzana et al. study on sensory impairment demonstrated that age-related sensory decline is based on the specific factor theory. The specific factor theory states that sensory decline in one sense is not correlated between the other senses. Simply stated, a decline in vision does not equal the same decline in touch or smell. The degree of impairment and prevalence in the senior population varies for each of the five senses.

### **2.1 Sight – Aging Vision**

Through the eyes, humans gather a great deal of information about their surroundings and about the food they are gathering or consuming. Around the age of 40, changes in sight start to occur (Pathai et al. 2013). These changes result in the need for brighter lighting and stronger contrast (Black, Kimlin, & Woods, 2014). In Cavazzana et al. study on sensory impairment, participants were tested and self-reported on sensory impairment (2018). Vision was one of two senses in which a high percentage of participants self-reported impairment. This demonstrates that senior citizens may be more sensitive to changes in vision due to the impact on day-to-day activities, such as reading and/or driving.

Flavor perception may be impacted by these changes since the consumer may not be able to pick up on visual cues about food, such as the color, gloss, and shape (Zampini & Spence, 2012; Delwiche, 2012). Consumers may infer the flavor of a food product based on the color and associate color intensity with flavor intensity. For example, an orange-colored beverage is assumed to be orange-flavored and when that assumption is proven wrong, then the consumer's food liking is decreased due to the cognitive dissonance (Appleton & Smith, 2015).

The degree of vision impairment varies based on the individual and their medical condition. According to the 2014 National Health Interview Survey (NHIS), which was conducted by the Census Bureau for the National Center for Health Statistics, approximately 13.5% of seniors self-reported vision loss (CDC, 2015). This estimate may be lower than the actual prevalence since NHIS interviewers asked, “Do you have any trouble seeing, even when wearing glasses or contact lenses?”. This estimate of 13.5% of seniors covers the severe cases of vision impairment that cannot be corrected. Since the visual cues are a consumers’ first impression of food products, it is important to keep in mind that a percentage of senior consumers may not be able to overcome their impairment.

## **2.2 Audition – Troubled Hearing**

Hearing is important in day-to-day activities, from listening to music and conversations to listening to our surroundings for potential dangers or alerts. With age, hearing is impaired by the loss of hair cell in the inner ear, thickening of the eardrum, and/or damage in the auditory nerve cells (Zampini & Spence, 2004). This could be the result of general aging or to repeated exposure to loud sounds or music over a long period of time. In Cavazzana et al. study, hearing was reported by 56% of participants as being impairment compared to their past selves (2018). This is probably most noticeable along with vision because these two senses affect daily interactions with the environment and other people.

For food perception, different auditory cues can be picked up from the crunch of food while chewing to the sound of packaging (Spence & Shankar, 2010). Impaired hearing generally results in reduced intensity of crispness or crunchiness which reduces the feeling of freshness of food products (Zampini & Spence, 2004). Although these are the impacts of hearing impairment,

there are no reported negative effects on food texture perception and food liking (Doets & Kremer, 2015). Auditory cues for texture may be compensated by a different sense.

### **2.3 Olfaction – Difficulty Smelling**

The human sense of smell has an important role in detecting dangers in the environment, such as spoiled food, natural gas leaks, and other unsavory smells. It is also linked with detecting pleasurable scents from flowers to foods. Aromas are also closely linked with memories (Waskul et al., 2009; Schab, 1990). In food perception, the aroma of food products is a key part of building excitement towards consumption, tasting, and experiencing the flavors. Generally, people are intrigued or start salivating based on the aroma of food. For example, Thanksgiving dinner is hallmarked by the orchestra of aromas from the roasting turkey, stuffing, cranberry sauce, green bean casserole, to many more items. The aroma of food could also be a key indicator that the food is spoiled and would be harmful to eat, such as when milk spoils. In cases of severe olfactory impairment such as anosmia, offending odors are undetected and potentially result in the consumer ingesting spoiled food or signs of a life-threatening event such as smoke from a fire (Doty, 2018). Unfortunately, olfactory impairment occurs with increased age, even in healthy adults (Ship et al., 1996).

Olfactory impairment is the result of various cumulative changes and damages to the nose, receptors, brain structure, and/or chemistry. There are six main causes for olfactory impairment: environmental pollutants, age-related decline in receptor cell regeneration, age-related decrease in neuropathways from olfactory receptors to the brain, decreased immune resulting in decreased maintenance of the epithelium, compromised response in receptor cells, and neurological diseases such as Alzheimer's and Parkinson's (Doty, 2018). In several studies, brain activity was observed to compare olfactory processing in seniors and younger adults. It was

discovered that seniors demonstrate significantly less activation in brain regions involved with olfactory processing compared to younger adults (Cerf-Ducastel & Murphy, 2009). Additionally, seniors demonstrated more activation of the cerebellum which suggests that the act of smelling requires greater attention or uses other neural pathways to compensate for any perceived gaps (Cerf-Ducastel & Murphy, 2003, 2009). Severe olfactory impairment has been linked to neurodegenerative diseases, specifically Parkinson's disease and Alzheimer's disease (Conti et al., 2013; Braak et al., 1998). In a study done in the Netherlands, the general olfactory impairment occurrence rate in the senior population is ~30% (Toussaint et al., 2015). According to the U.S. National Social Life Health and Ageing Project, 2.7% of participants demonstrated severe olfactory dysfunction (Boesveldt et al., 2011). These different values for the rate of olfactory impairment prevalence demonstrates how olfactory impairment may be under-reported or overlooked.

Although olfactory impairment prevalence is variable, it seems to be a common occurrence that is not generally noticed when compared to visual and/or auditory impairment. The degree of olfactory impairment is dependent on the type of odorant (Doets & Kremer, 2016). According to Joussain et al. (2013) and Konstantinidis et al. (2006), the identification of unpleasant odors was the same between young adults and seniors, whereas identification of pleasant odors was decreased among seniors when compared to young adults. This indicates that danger identification and avoidance is the key feature of the sense of smell. For food, this results in a lower intensity score from seniors, but offending odors would be scored similarly when comparing results from seniors to younger adults. Mojet, Heidema, & Christ-Hazelhof tested the role of olfaction on taste perception on foods with and without a nose clip on healthy independent seniors and young adults (2004). It was discovered that the perceived intensity

rating among seniors was similar between the two conditions: nose clip on and nose clip off. Whereas young adults showed a greater difference in perceived intensity rating under the two conditions. This clearly demonstrates the importance of olfaction on food perception.

## **2.4 Gustation – Tasting Troubles**

Taste is key for all food products. Most people confuse taste with flavor. Flavor is the combined experience of aromas and tastants. There are five basic tastes: sweet, sour, bitter, salty, and umami. There are various causes for the change in taste perception because of the different biochemical pathways for tastant detection on taste buds.

Taste starts with the taste buds that are contained in the various types of papillae located on the tongue. These taste buds contain different taste cells that have an average lifespan of 8-12 days (Doets & Kremer, 2016). Despite cell regeneration, sensory perception of the basic taste attributes changes over a lifetime with no conclusive cause. Some studies show that aging may reduce the number of taste buds, papillae, or the density of taste buds on the tongue (Fischer et al., 2013; Shimiza et al., 2007). Other studies show little to no changes in the number of taste buds (Seiberling & Conley, 2004). Another study indicates that the regeneration of taste buds decreases or changes with time (Feng, Huang, & Wang, 2014). Additionally, seniors with poor dental health are not able to masticate food as efficiently which results in less tastants released for taste cells to detect along with the changes in taste receptors. There is no simple explanation since each of the basic tastes are impacted differently (Doets & Kremer, 2016). Additionally, some medications may impair or alter taste perception.

Multiple studies have explored taste perception between young and older adults. There are three main focuses to examine taste impairment: taste detection thresholds, identification/recognition thresholds, and taste intensity perceptions (Methven et al., 2012).

Participants evaluated aqueous solutions with a single tastant at varying concentrations (Schiffman et al., 1990; Schiffman et al., 1994; Kaneda et al., 2000; Fukunaga et al., 2005; Mojet et al., 2005; Kremer et al., 2007; Methven et al., 2012; Doets & Kremer, 2016; Boesveldt et al., 2018). Additionally, multiple compounds were used for each of the basic tastes, such as sodium chloride and potassium chloride for salty, citric acid, tartaric acid, and acetic acid for sour, quinine and caffeine for bitter, monosodium glutamate and inosine monophosphate for umami, and sucrose and aspartame for sweet. Analysis of these studies showed a significant difference in basic taste detection threshold of salty, sour, bitter, and umami of older adults in comparison to younger adults ( $p < 0.05$ ) (Schiffman et al., 1990; Schiffman et al., 1994; Kaneda et al., 2000; Fukunaga et al., 2005; Mojet et al., 2005; Kremer et al., 2007; Methven et al., 2012; Doets & Kremer, 2016; Boesveldt et al., 2018). Exact detection threshold value increases varied based on the methodology, the tastants used, and the participants.

For salty taste, NaCl was a commonly used tastant. The mean salt detection threshold among younger adults was 0.06% w/w whereas older adults was 0.12% w/w. This is a two-fold mean salt detection threshold increase among older adult (Methven et al., 2012). For sour taste, citric, tartaric, and acetic acids were commonly used tastants. The mean sour detection threshold increased by 1.5-fold (Methven et al., 2012). For bitter taste, quinine and caffeine were the commonly used tastants. The mean bitter detection threshold increased by 1.2-fold for caffeine and 4-fold for quinine (Methven et al., 2012; Doets & Kremer, 2016). For umami, monosodium glutamate was commonly used as the tastant. The mean umami detection threshold increased by 2.2-fold (Methven et al., 2012; Doets & Kremer, 2016). Sucrose was the commonly used tastant for sweetness. Results varied in multiple studies. For example, Kaneda et al. reported there was no significant difference in detection thresholds from young to elderly (2000). But a couple years

later, Fukunaga et al. reported that there was a significant increase ( $p < 0.0001$ ) in the recognition threshold for sucrose (2005). Overall, the observation was that there is no increase in detection threshold for sweetness with increased age (Methven et al., 2012; Doets & Kremer, 2016). Though these results vary in terms of the exact degree of impairment, they show us that there is an impact of age on the tastant detection and recognition thresholds in aqueous solutions.

Though these taste impairments are observed and can be quantified with some consistency, the prevalence varies based on the individual and their experiences. Boesveldt et al. found that severe cases of taste impairment, defined as  $<25\%$  accuracy in gustatory tests, occurred in approximately 10-15% of the senior participants ( $n=3005$ , mean age of 69) (2011). As demonstrated by the varying degrees of taste impairment on each of the basic tastes, there is no scientifically agreed cause. Each of the basic tastes are involved with different chemical receptor mechanisms which explains the variability of detection threshold increases for different tastants.

## **2.5 Food Texture and Mouthfeel**

Texture is a critical component that is commonly overlooked in favor of taste and aroma. But some food products are defined by their texture, whether it is creamy ice cream or crispy and crunchy chips. Previously mentioned, the dental health of seniors is variable to individual life experiences. Some boomers may have retained all their teeth, missing some of their teeth, or are already using dentures. Seniors with poor dentition have found masticating cereal products and meat products more painful (Vandenbergh-Descamps et al., 2016). Not only is chewing more difficult, but some may suffer from difficulty swallowing or dysphagia. Among seniors, there are two main type of dysphagia: oropharyngeal and esophageal (Aslan & Vaezi, 2013).

Oropharyngeal dysphagia commonly is caused by strokes, occurring in approximately a third of stroke patients. Whereas esophageal dysphagia is caused by various mechanical/muscular causes, such as head or neck injuries, Parkinson disease, Huntington disease, multiple sclerosis, dementia, and side-effects of medical prescriptions. Both medical conditions, poor dental health, and dysphagia would very likely reduce food liking, appetite, and food consumption.

The prevalence of poor dental health is highly variable based on social-economical status. In industrialized societies like America, more than 50% of seniors lack teeth to some degree (Razak et al., 2014). Dysphagia generally has a prevalence of 6-9% of the US population (Aslan & Vaezi, 2013). For seniors, the prevalence of dysphagia increases to 15-22% (Aslan & Vaezi, 2013). The increased prevalence of poor dental health and dysphagia with age reflects the cumulation of the impact of individuals' social-economic status, pre-existing medical conditions, and/or injuries throughout their lives.

For independent seniors, not living in long-term care facilities or hospitalized, these impairments are things they have adapted to by avoiding certain foods, preparing foods in a way to ease consumption, and/or eating with more care. A lot of responsibility and pressure is placed on the consumer, who may be managing more than one medical condition. There is great variability in dental health and swallowing ability, it is very important that texture and mouthfeel is considered in food products for seniors. This attribute could be considered critical since it is unlikely for consumers to purchase and consume products that are difficult to eat.

## **2.6 Sensory Perception, Expectations, Mental Health & Food Liking**

Despite lowered sensory abilities, these impairments are not associated with reduced food liking (Kremer et al., 2007). Food liking is based on more than just sensory perception.

Consumer develop their opinion of foods based on a variety of information that builds their expectations and how those expectations may or may not be met. These expectations are formed based on accumulated experiences from previous sensory experiences, consumption contexts as well as other associated learnings (Mela, 1999). The context of food consumption can be related to the product brand, the images and the claims, consumers' psychological and physiological state, as well as the situation and frequency of consumption (Mela, 1999; 2000; 2006; Reis, Alcaire, Deliza, & Ares, 2017; Lidon et al., 2018; Morris, Beresford, & Hirst, 2018; Santagiuliana et al., 2019; Nguyen & Wismer, 2019; Torrico et al., 2019). Some of these consumer food experiences are associated with their cultural background or accessibility to try other cultural cuisines which results in product familiarity (Torrico et al., 2018; Mela, 2000). The resulting differences between expectation and actual sensory experience are psychologically resolved by the consumer. There are some theoretical models (assimilation, contrast, generalized negativity, and assimilation-contrast) that explain the impact of the differences between expectation and actual experience (Piqueras-Fiszman & Spence, 2015).

The assimilation model depicts consumers resolving differences by shifting sensory perception ratings to meet expectations set, whereas the contrast model depicts differences being magnified and not meeting expectations (Piqueras-Fiszman & Spence, 2015). Generalized negativity model suggests that any differences between expectation and experience result in a negative opinion regardless of how the actual experience was (Piqueras-Fiszman & Spence, 2015). For example, a consumer that has a generalized food aversion will generally dislike food products that contain their aversion. Assimilation-contrast model suggests that assimilation or contrast could occur based on how big the difference is (Piqueras-Fiszman & Spence, 2015). For example, pink-colored ice cream. Pink-colored ice cream is generally expected to taste like

strawberry based on consumer food memory, but if the ice cream was raspberry then consumers may assimilate the experience and still have a favorable impression of the product. But if the pink-colored ice cream is salmon flavored or bubblegum flavored, then consumers may follow the contrast model since the difference between expectation and experience is too great, which would result in an unfavorable impression of the product.

Beyond the psychological resolution of expectations and reality is the consumers' mental health or state-of-mind. Seniors face a lot of changes and need to overcome personal hurdles, such as coming to terms with physical limitations, medical conditions, and eventually mortality. It may not even be their own mortality; it could be the death of friends or even their spouse. All these changes may leave these seniors feeling helpless and may lead to depression. Who wouldn't feel helpless and depressed if you had reduced capabilities compared to younger years, potential diet changes or additional medication for medical conditions, or a shrinking group of friends? Depression is a real issue that impacts at least 2 – 10% of older adults living in retirement communities and at least 30% of nursing home residents (Evers & Marin, 2002). What does this have to do with food though? With depression in older adults, they may exhibit a loss of interest or pleasure in once enjoyable activities, such as eating. For older adults in nursing homes, this loss of interest in food has resulted in a 30-36% loss of weight (Morely & Kraenzle, 1994). In case of a spouse's death, the psychological impact of bereavement on the widowed is profound. Rosenbloom and Whittington (1993) noted that 73% of widows (n= 44) commented on loneliness and diminished enjoyment at mealtimes and that eating became a chore. Along with a grim outlook on food is weight loss, 84% of the widows in the study reported weight loss which averaged to 7.6 pounds (Rosenbloom & Whittington, 1993). The mental health of senior consumers has a serious impact on their appetite and changes how they view food.

Food liking is complex. It is based on consumers' mental state, preferences, previous experiences, sensory abilities, intrinsic factors, and extrinsic factors of the product itself. Sensory perception is one component that forms the bigger picture of food choice and want. For senior citizens with impaired senses, the intrinsic strategies and extrinsic strategies should be implemented in tandem to manage consumer expectations and food hedonics to promote nutritional health and healthy aging.

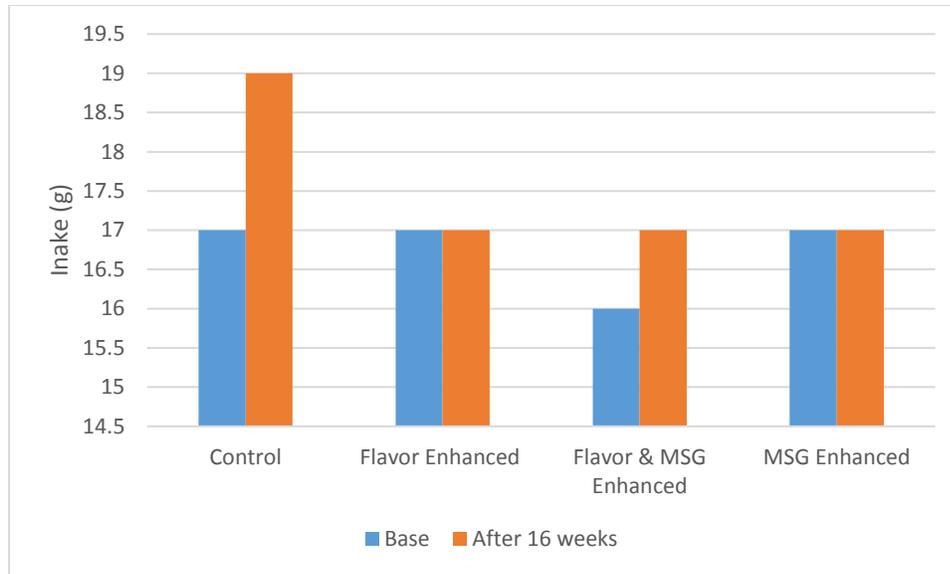
### **3. Impact on Food Products: Solutions to Improve Nutritional Intake**

The prevalence and severity of sensory impairment in the senior demographic results in a very heterogeneous market segment. As established by Kremer et al. (2007), sensory impairment is not associated with reduced food liking. This information is not enough to understand why older adults demonstrate lower rating for liking in comparison to younger adults, and why this demographic is at-risk for malnutrition (Appleton & Smith, 2015; Methven et al., 2012; Doets & Kremer, 2014). Nutritional status is a key predictor of frailty and additional medical issues relating to physical and mental health (Doets & Kremer, 2014; Esquivel, 2017; Artaza-Artabe L. et al, 2016). All compounded medical issues would lead to a poorer quality of life. It is critical that food development strategies are implemented to help improve the nutritional status of seniors and to promote healthy aging. These strategies can utilize intrinsic manipulations of food to improve liking and intake and/or extrinsic methods to entice or improve or inform the consumption expectation and experience. A combination of intrinsic and extrinsic strategies should be used to maximize the desired effect.

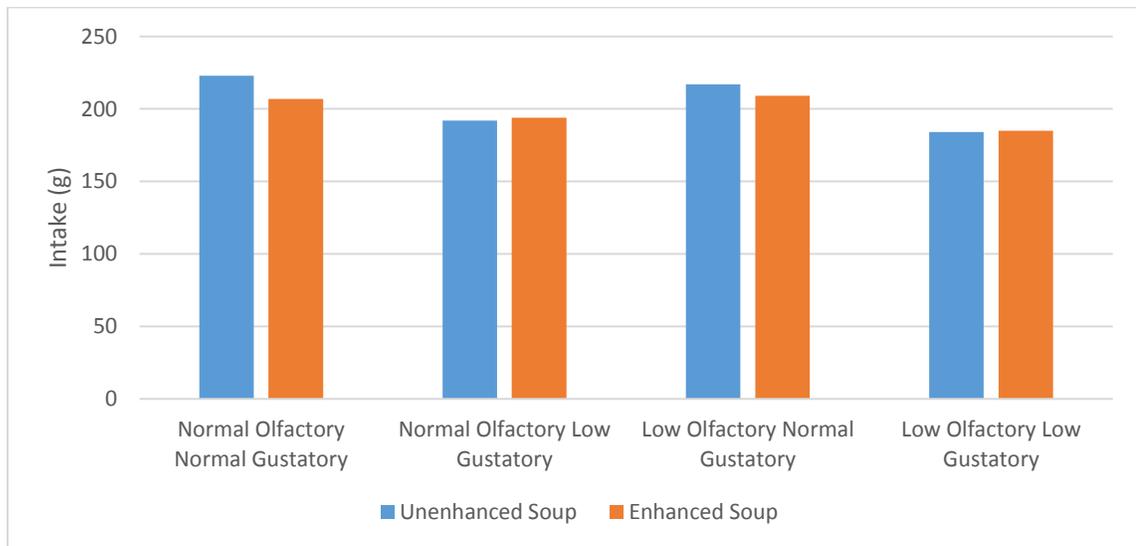
#### **3.1 Intrinsic Strategies**

There are three main intrinsic strategies to overcome age-related sensory decline: flavor enhancement, texture modification, and increased visual identification (Doets & Kremer, 2016; Abdel-Moemin et al., 2019).

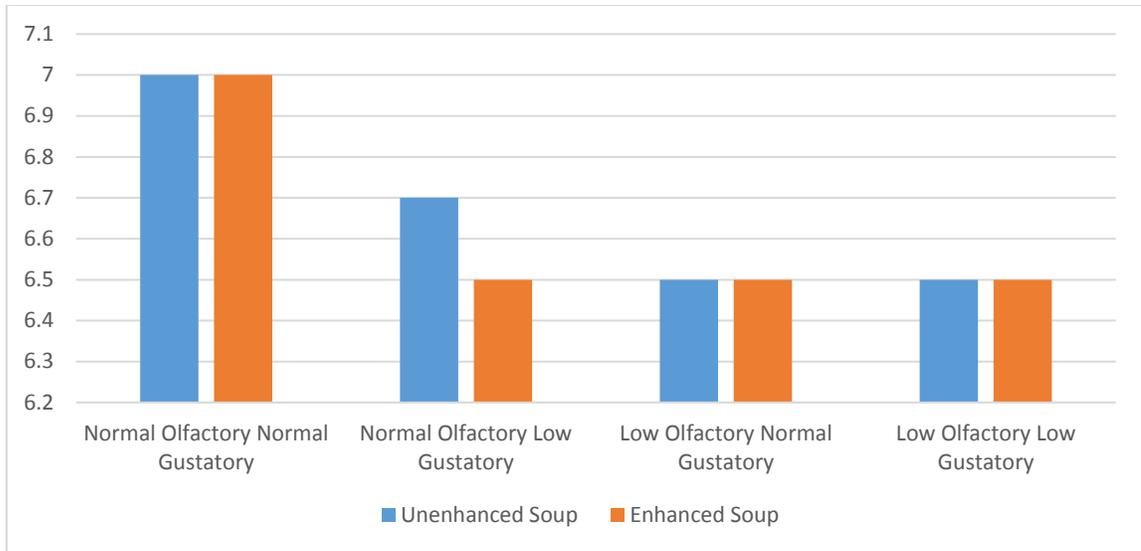
Flavor enhancement is a straight-forward strategy to address olfactory and gustatory impairment (Abdel-Moemin et al., 2018). Based on the literature, this strategy has mixed results (Schiffman et al., 1994; Griep, Mets, & Meassart, 1997; Koskinen, Kalviainen, Tuorila, 2003; Kremer, Mojet, & Kroeze, 2005; Essed et al., 2007; Essed et al., 2009; Doets & Kremer, 2016). For instance, Schiffman's 1993 study on the taste perception of monosodium glutamate (MSG) established that senior participants (n=10) required approximately three times more MSG in various food matrices to recognize the taste of umami as compared to younger participants. In 1997, Griep, Mets, and Massart performed a study which demonstrated seniors preferred highly flavored soups with increased MSG. A decade later, Essed (2007) tested the theory in their study to see if increased MSG in foods served to seniors in nursing homes would improve their food liking, intake, and/or nutritional status. In both Essed's 2007 and 2009 study, increased MSG in animal protein meals and tomato soups demonstrated no increase in food liking, food intake, and improved nutritional status among seniors with taste and smell impairments (Figure 1, 2, 3).



**Figure 1: Protein intake of nursing home elders with and without flavor enhancement before and after 16 weeks (Essed et al., 2007)**



**Figure 2: Intake of plain and enhanced tomato soup of independently living older adults divided into four groups of olfactory and gustatory performance (Essed et al., 2009)**



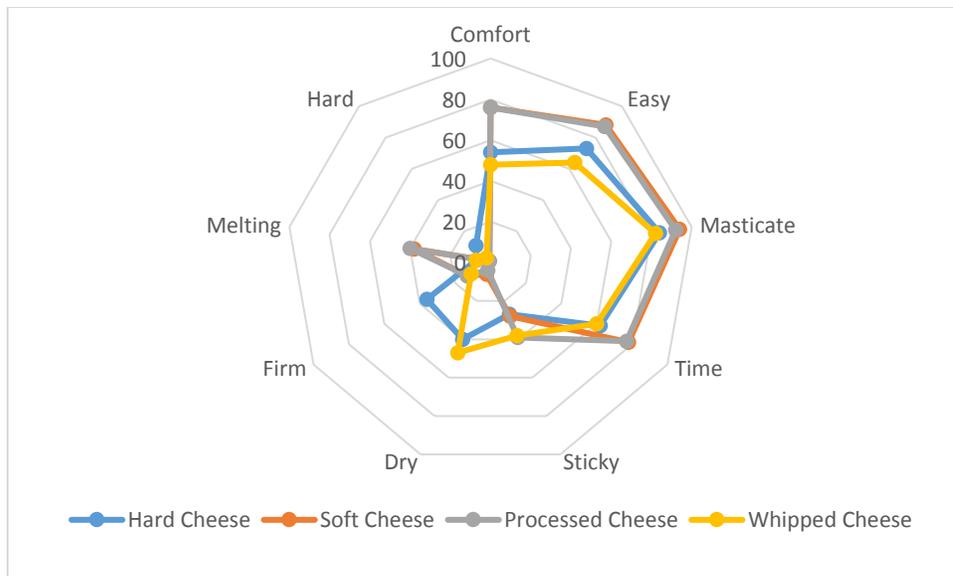
**Figure 3: Liking of plain and enhanced tomato soup of independently living older adults divided into four groups of olfactory and gustatory performance (Essed et al., 2009)**

The effectiveness of flavor enhancement is dependent on many variables, such as the product category, the desired flavor, and tastant being enhanced. Each of the basic tastes are negatively impacted at different rates as seen by the varying detection threshold increases. Additionally, it would not be beneficial to increase the tastant if there would be negative health consequences. For example, increasing the sucrose or sodium chloride content in a food product to increase perceived sweetness or saltiness may exacerbate existing health conditions or increase the risk of getting diabetes or hypertension. If increasing the tastant is not an option, then increasing the aromatic flavor compounds may be viable. But this idea was disproven by Koskinen, Kalviainen, and Tuorila's (2003) study, which revealed aroma increase did not significantly increase intake among seniors and negatively impacted younger consumers by decreasing their willingness to buy, to eat the product again, and to recommend the product to a friend. Based on Forde and Delahunty's 2003 study on orange juices for young and senior consumers, senior consumers are including textural influences into their liking evaluation

whereas young consumers primarily base their liking evaluation on taste and smell. Instead of focusing on overcoming chemosensory impairment, it would be best to diversify.

Texture modification, such as minced, pureed, increased viscosity, aids seniors with impaired mastication and/or gustatory abilities to improve liking and intake. Dental health among seniors varies. In cases of poor dental health, food perception may be impacted by the change in flavor release or texture. Impairment may cause the experience to be discomforting or painful. By modifying the texture of food products, mastication would be easier and the amount of tastants released would be increased (Abdel-Moemin et al., 2019). By improving food comfortability, the perceived ease of eating also improves (Lorieau et al., 2018). Additionally, texture modification would aid older consumers with difficulty swallowing or dysphagia. These textural improvements to the eating experience would improve food likeability and consumption. But it is important to note that minced, pureed, and liquidized foods are not visually appealing which would potentially decrease consumption and would have lower nutritional content compared to solid forms (Stahlman et al., 2000; 2001). But not all food products can be minced, pureed, and/or liquefied. Some foods can be softened due to the cooking process, such as soups and stews. These products can contain meat and vegetable pieces that are softened, which implies ease in mastication and swallowing (Strangierski & Kawecka, 2019). Some of these products may also have a high viscosity, which is beneficial to seniors with swallowing problems (Stelt et al., 2020). But in the case of hard or solid foods, what may be more important is the ease of forming a food bolus and the final texture of the food bolus. This is what was explored in Lorieau et al. (2018) study on the bolus quality and food comfortability of four model cheese for seniors. Cheeses that required more saliva or liquids resulted in a harder bolus and was described by participants as least comfortable. The unfavorable texture attributes were identified as dry and

sticky. Favorable texture attributes were soft, fatty, and melty. This resulted in a more easily formed bolus and was more comfortable to senior, which had a positive impact on food liking and comfort (Figure 4). A “mouthfeel wheel” of texture attribute terms was developed by van der Stelt et al. (2020) for medical nutritional products. The developed terms echo the desirable and undesirable attributes discovered by Lorieau et al. (2018). But there are some key texture attributes not captured by Lorieau et al. For example, mouthfeel attributes pertaining to “mouth effect” or “throat effect after swallowing” were not captured by Lorieau et al. Some pleasant mouthfeel attributes were “mouth tingle”, “cooling in the throat”, “smooth” whereas some unpleasant mouthfeel attributes were “metallic effect”, “throat irritation”, “mouth coating”, “gagging reflex” (van der Stelt et al., 2020). The use of a mouthfeel wheel of texture attribute terms would be beneficial to developing food products for independent senior consumers that are not in long term care facilities nor need to consume medical nutritional products. Overall, texture modification methods should be considered carefully based on the product category to improve food liking and food intake.



**Figure 4: Results from questionnaire on perception of food comfortability (Lorieau et al., 2018)**

Finally, the visual identification cues could be increased for better identification or contrast. All consumers “eat with their eyes” and set the food consumption expectations based on visual cues. Older adults are no different. Increased visual cues help with cognitive associations with food and can compensate for flavor impairment and texture modified foods (Appleton & Smith, 2015; Doets & Kremer, 2016; Stahlman et al. 2000; 2001). Santagiuliana et al. (2019) study on consumer expectation of chicken soups with vegetable pieces at three different sizes (3mm<sup>3</sup>, 7mm<sup>3</sup>, and 10mm<sup>3</sup>), model carrot pieces (carrot-flavored agar gels at 7mm<sup>3</sup>) and model chicken pieces (chicken-flavored agar gels at 7mm<sup>3</sup>) demonstrated the influence of visual interest on expected textural attributes as well as flavor perception. The model chicken pieces were not visually aligned with consumer expectations and resulted in a significant decrease in liking, but model carrot pieces visually aligned with expectations of real carrots. The size of the carrot pieces influenced texture expectations from consumers, with larger pieces increasing the perception of crunchy, chewy, or hard carrot pieces whereas medium to small pieces were perceived to be softer and better aligned with expectations developed from previous chicken

soup consumption experiences. Samples developed in the study that closely resembled consumer expectations of the product improved sensory perception and liking of the soups. This can be easily applied to other food products. The more identifiable and familiar the food item is, the more likely the product can be perceived as pleasant or likeable.

Flavor enhancement, texture modification and increased visual identification are strategies that should be used in tandem to develop food products with intrinsic characteristics that appeal to seniors as well improve their experience.

### **3.2 Extrinsic Strategies**

There are three extrinsic strategies that help seniors with their food choice, intake decisions, and improve product liking: packaging, labeling, and the evocation of memories and emotions (Doets & Kremer, 2016; Abdel-Moemin et al., 2019).

Packaging is an important element of food products. It is the delivery system as well as the protectant. But sometimes packaging can be cumbersome and difficult to open, which could have a negative impact on the product experience. For seniors, difficult packaging can especially frustrating if they suffer from osteoarthritis in their hands. Osteoarthritis is the most common form of arthritis that affects approximately 15% of the general population, with age and gender as a strong predictor of osteoarthritis and is commonly associated with the hand, knee, and hip joints (Johnson & Hunter, 2014). Women are associated with higher prevalence and severity as compared to men. Though there is no reported prevalence among the senior population, it is easy to imagine the prevalence is high when the lifetime risk is 40-47% (Johnson & Hunter, 2014). The best way to increase accessibility is to make food packaging easy-to-open and easy-to-reclose. This type of packaging promotes a feeling of independence and improves food product liking (Abdel-Moemin et al., 2018). Increased color contrast, such as dark text on a white

background, on packaging would allow for greater accessibility to consumers with visual impairment (Abdel-Moemin et al., 2018; Doets & Kremer, 2016). Additionally, individual portion-sizing would be helpful for independent-living seniors that no longer need to prepare family-sized meals (Abdel-Moemin et al., 2018; Doets & Kremer, 2016). In general, consumers of all ages can benefit from packaging improvements for increased accessibility and individualization.

Labeling is another aspect that influences product likability (Doets & Kremer, 2016). Based on the labeling, the product likability and perceived healthiness of food are impacted (Ekelund et al., 2007; Faulkner et al., 2013; Johansen et al., 2010). Branding of products generate different expectations from consumers regarding the quality (Morris, Beresford, & Hirst, 2017). Specialty product brands and/or premium brands were regarded as high quality with product expectations being high, while private label (everyday retailer) brands and/or discount (retailer) brands were regarded as lower quality with product expectations being lower. With private label and discount brands, consumers assimilated any intrinsic flaws of the product to expected lower quality based on the brand. This would not be true of specialty product brands or premium brands. It could be inferred that a reduction of quality in specialty and premium brands would result in dissonance and may negatively impact consumer liking of the product. But branding has a limited impact on sensory evaluation and product liking but is a factor that influences consumer expectations and purchase intent (Morris, Beresford, & Hirst, 2017). Health claims or ingredient claims, such as reduced sodium or reduced sugar, also influence consumers and product expectations. There are various food products on the market with such claims or labels, but the question is, what do consumers think of these.

In the case of products with declared reduced sodium, the products were perceived as less salty but other product sensory attributes were also impacted (Nguyen & Wismer, 2019). Some reduced sodium food products were liked better than their “regular” sodium products, such as pickles. But for other products, such as ham, sodium reduction resulted in less juicy texture characteristic since sodium helps with the water binding capacity of meat proteins. Despite divergent impacts on products, these sensory changes were rated as acceptable to consumers (Table 1) (Nguyen & Wismer, 2019).

**Table 1: Overall liking of regular and sodium-reduced food products (Nguyen & Wismer, 2019)**

Food Product	Regular	Sodium-Reduced
Chips	6.8 ± 1.4	6.8 ± 1.4
Pickles	5.3 ± 1.9	5.8 ± 2.0
Ham	6.1 ± 1.4	6.0 ± 1.7
Soup	6.6 ± 1.4	6.1 ± 1.6
9-Point scale of 1 (Dislike extremely) to 9 (Like extremely)		

The same could be said with sugar reduced products. In a case study about orange pomegranate juice, researchers developed five samples of orange pomegranate juice using no added sugar, added sugar, and sweetened with other sweeteners such as sucralose, stevia, and monk fruit extract (Reis, Alcaire, Deliza, & Ares, 2017). The samples were presented under two conditions: blind and informed. The results demonstrate, on average, that information generally increased overall liking scores of the various orange pomegranate juice blends; looking at individual variables, the sample with no added sugar had a significant difference (Table 2). This study also demonstrated that information pertaining to certain ingredients, such as stevia, would affect sensory and hedonic perception through the assimilation model. The *non-characteristic flavor* of stevia would be assimilated into consumer’s expectation and perception based on the product labeling. But some natural sweeteners, like monk fruit extract, the *non-characteristic*

*flavor* diverged too much from a “regular” product which results in a negative perception of the product through the contrast model. This demonstrates the positive impact of nutritional characteristic labeling on consumer perception of products through the management of expectation.

**Table 2: Average overall liking scores of orange/pomegranate juice under blind and informed conditions (Reis, Alcaire, Deliza, & Ares, 2017)**

Sample	Blind	Informed	Significantly Different?
Sugar	5.8 ± 2.2	6.4 ± 1.9	NS
No Added Sugar	3.4 ± 1.9	4.0 ± 2.1	SD
Sucralose	5.9 ± 2.2	6.2 ± 2.1	NS
Stevia	5.8 ± 2.2	5.5 ± 2.3	NS
Monk Fruit Extract	4.1 ± 2.4	4.4 ± 2.4	NS
Average Overall Liking Score	5.0 ± 1.9	5.3 ± 1.9	SD
9-Point scale of 1 (Dislike extremely) to 9 (Like extremely) NS = Not Significantly Different SD = Significantly Different (p < 0.05)			

Additionally, consumers are willing to pay more for products with front-of-pack labeling that indicates a “healthier choice”, reduced sugar/MSG/sodium, other health benefits, or locally sourced ingredients (Bugera, Lengyel, Utioh, & Arntfield, 2013; McCrickerd, Tang, & Forde, 2020). For example, Bugera (2013) developed a tomato lentil pasta sauce with functional food properties utilizing locally sourced ingredients to understand consumer acceptability among baby boomers and how much they were willing to pay the product. Based on the participant suggested pricing, on average, they were willing to pay \$0.34 more compared to commercially available products (Bugera, Lengyel, Utioh, & Arntfield, 2013). Labeling plays a role of informing consumers and managing their expectations which ultimately influences the consumers’ perception and liking of a product. With seniors placing more emphasis on health food products,

they would want to see labeling that guides them to the right foods that align with their goals and proper labeling would help mitigate some sensory impairment with psychological influence.

The last extrinsic strategy to help seniors with food choice and intake decision is to evoke positive memories or emotions associated with food. Evoking memories is favorable to product liking and consumption (Doets & Kremer, 2015). It is the mental-emotional factor that should not be ignored for any consumer experience. By evoking positive memories or emotions, the food product is facilitating cognitive associations to previous favorable food experiences that can compensate for sensory perception gaps. This would also include product familiarity. The consumers' familiarity to a product, a type of product, or an ingredient plays an important role in liking (Torrìco et al., 2019). For example, monk fruit, or *luo han guo*, is a familiar ingredient in Chinese culture since the plant is native to southern China and is used in traditional Chinese medicine as a treatment for coughs and sore throats (Li et al., 2014). In America, this fruit is processed and used as a sweetening agent. Most Americans are not familiar with the flavors associated with monk fruit, which generally results in a negative perception of food products sweetened with monk fruit. On the other hand, mac and cheese and apple pies are well-known food dishes or products in America which allows the American market to accept and like these products more readily. This familiarity to ingredients and/or products allows seniors to feel comfortable with their decisions and allows for previous food experiences to become a reference point of cognitive assimilation to overcome sensory perception gaps.

These extrinsic strategies improve accessibility, inform consumers, manage expectations, and leverage familiarity of food products to potentially improve product liking. This is especially important when intrinsic strategies are not the cure-all to overcoming sensory impairment and

improving nutritional health. Healthy aging involves consumers to make the conscious choice to select products that align with their health and diet goals.

#### **4. The Current Market for Baby Boomers and Seniors**

Retail food products are generally not marketed “for seniors” because it is not appealing to the target consumer. It is not desirable to ostracize a specific demographic for age-related changes. But Boomers will be and are the seniors of the American population. Their needs should be addressed, but should their products be age-specific?

When age-specific products are mentioned the general population probably thinks of children. In the case of foods, it is very easy to notice what products are targeting children. There is bright bold packaging with cartoon characters or iconic role models. The food product is generally colorful with novel shapes and/or sizes. Maybe the product is marketing a toy inside to encourage the child to ask for their parent to purchase it. What would older adult foods look like on the shelf without making the consumer feel ashamed or outraged? It is likely due to these negative feelings that many food products are not senior specific.

As older consumers, this group is looking for health and wellness (Mintel, 2019). The main drivers of food purchases are health benefits, taste, and price (Bugera et al., 2013). Bugera noted that local sourcing of familiar ingredients improved consumer’s purchase intent. But how is this any different from a regular consumer? To this point, there is some distinction on what health claims catches the senior consumer’s eye.

There are a variety of health claims and benefits on the current market, from no added sugar, low sugar, heart healthy, whole grain, low sodium, low fat, immune boosting, and so on. But what are the key concerns of Baby Boomers? According to Krystallis et al. (2008) and Urala & Lahteenmaki, (2004; 2007), Boomers associate the following label statements as healthy:

whole grain, high fiber, free of trans fats, low sodium, fresh, heart healthy, and low fat. More specially, seniors look for food products that help with disease prevention. Food products that state they are high in antioxidants, vitamins, and minerals with a specific health purposes would likely catch their attention.

Though these are the claims older consumers are looking for, there are certain nutrients that shouldn't be ignored. As mentioned, frailty and sarcopenia are two of many chronic conditions that older adults are at risk of. Both conditions are preventable through proper nutrition. What is missing from the health claims seniors are looking at? Protein, calcium, and vitamin D might be some of the nutrients missing. The decline in muscle mass of elderly individuals has been attributed to the low consumption of protein in their diets (Stenholm et al., 2008). According to World Health Organization (2007), the recommended daily protein intake of 0.8g/kg is not enough for the maintenance of muscle mass. According to Valenzuela et al. (2013), one-third of elderly women and one-quarter of elderly men consume less than the recommended amount of protein. Artaza-Artabe et al. (2016) recommend that older adults should consume 25-30g of protein per meal, 1000-1200mg of calcium per day, and more than 800UI of vitamin D per day to improve bone and muscle health and reduce the risk of falls and accidents. As the current market stands, most high protein products are marketed toward muscle builders and fitness enthusiasts.

High protein products generally come in the form of concentrated powders for consumers to incorporate into their diet, or nutritional beverages for direct consumption as meal replacements or supplement. Other high protein products are ready-to-eat/drink bars and beverages. The protein source for these products are generally whey or soy. Other plant-based proteins have been commercialized such as pea protein and hemp protein but are uncommon.

Unfortunately, most consumers do not like commercially available protein beverages (Childs et al., 2008). A focus group study was conducted to understand the consumer perception of protein beverages and bars, consumers stated the top three factors that influence purchase was nutritional content, flavor, and price (Childs et al. 2008). These are the same drivers that influence older adults in their purchases. Additionally, most consumers in the focus group favored heart health claims and low-fat labels. Both claims align with what older adults seek. It would not be hard to imagine with some changes to product positioning that these high protein products would be beneficial to seniors' health goals.

## **5. Conclusion**

Older adults experience sensory impairment as part of the natural process of aging, but impairment does not mean these consumers cannot appreciate foods as they did before. These consumers rely more on additional information to guide their decisions on food purchases, intake, and liking. The current market may understand this based on the lack of age-specific product and general trend towards health claims that seniors also look for to achieve their health goals. But there are some overlooked claims that should be elevated to address the two chronic conditions of frailty and sarcopenia: high in protein, calcium, and vitamin D. These nutrients are critical to maintaining healthy lean muscle mass and strong bones which are important to mobility. Without the ability to move about independently, seniors lose self-confidence and their quality of life may start to diminish and increase their risk of mortality.

To better food products and promote healthy food choice and consumption among older adults, future research should be explored in two directions: expanding our knowledge and communication of food texture and the influence of context (claims, environment, eating occasions, etc). A better understanding of food texture and additional communication tools

would help with the development of food products that are better suited for older adults with poor dental health. The context in which food products are presented would provide a broader picture of what drives consumers' food choice and consumption. The current industry focuses heavily on the sensory hedonics of a product, but rarely do they capture the big picture of how a product would fit into a consumer's lifestyle and health goals. A better understanding of the influence of context not only helps the food industry promote healthy among older adults, but with the formation of healthy diets among all consumers.

Though there is no panacea to address the heterogenous mix of impairments and severities of this demographic, but it is possible for the industry to be more cognizant and implement a variety of methods, beginning at the packaging and ending with the last bite, to better guide and encourage food consumption and liking towards healthy aging among independent older adults.

## References

- Abdel-Moemin, A. R., Regenstein, J. M., & Abdel-Rahman, M. K. (2018). New food products for sensory-compromised situations. *Comprehensive Reviews in Food Science and Food Safety*, *17*(6), 1625–1639. doi: 10.1111/1541-4337.12399
- Appleton, K. M., & Smith, E. (2015). A role for identification in the gradual decline in the pleasantness of flavors with age. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, *71*(6), 987–994. doi: 10.1093/geronb/gbv031
- Artaza-Artabe, I., Sáez-López, P., Sánchez-Hernández, N., Fernández-Gutierrez, N., & Malafarina, V. (2016). The relationship between nutrition and frailty: Effects of protein intake, nutritional supplementation, vitamin D and exercise on muscle metabolism in the elderly. A systematic review. *Maturitas*, *93*, 89–99. doi: 10.1016/j.maturitas.2016.04.009
- Aslam, M., & Vaezi, M. F. (2013). Dysphagia in the elder. *Gastroenterology & Hepatology*, *9*(12), 784-795. <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3999993/>.
- Black, A. A. Kimlin, J. A., & Wood, J. M. (2014) Stepping accuracy and visuomotor control among older adults: Effect of target contrast and refractive blur. *Ophthalmic and Physiological Optics*, *34*(4), 470–478., doi:10.1111/opo.12141.
- Boesveldt, S., Bobowski, N., Mccrickerd, K., Maître, I., Sulmont-Rossé, C., & Forde, C. G. (2018). The changing role of the senses in food choice and food intake across the lifespan. *Food Quality and Preference*, *68*, 80-89. doi:10.1016/j.foodqual.2018.02.004
- Boesveldt, S., Lindau, S.T., McClintock, M. K., Hummel, T., & Lundstrom, J. N. (2011). Gustatory and olfactory dysfunction in older adults: A national probability study. *Rhinology*, *49*(3), 324-330. doi: 10.4193/Rhino10.155.
- Braak, H., Vos, R. A., Jansen, E. N., Bratzke, H., & Braak, E. (1998). Neuropathological hallmarks of Alzheimer's and Parkinson's diseases. *Progress in Brain Research Neuronal Degeneration and Regeneration: From Basic Mechanisms to Prospects for Therapy, Proceedings of the 20th International Summer School of Brain Research*, 267-285. doi:10.1016/s0079-6123(08)64021-2
- Bugera, J., Lengyel, C., Utioh, A., & Arntfield, S. (2013). Baby Boomers acceptability of a tomato lentil pasta sauce. *Food Research International*, *52*(2), 542–546. doi: 10.1016/j.foodres.2013.03.017

- Cavazzana, A., Röhrborn, A., Garthus-Niegel, S., Larsson, M., Hummel, T., & Croy, I. (2018). Sensory-specific impairment among older people. An investigation using both sensory thresholds and subjective measures across the five senses. *Plos One*, *13*(8). doi: 10.1371/journal.pone.0202969
- Centers for Disease Control and Prevention. (2015). *BRFSS prevalence & trends data*. Retrieved from <http://www.cdc.gov/brfss/brfssprevalence/>
- Cerf-Ducastel, B., & Murphy, C. (2003). fMRI brain activation in response to odors is reduced in primary olfactory areas in elderly subjects. *Brain research*, *986*(1-2), 39-53. doi: [10.1016/S0006-8993\(03\)03168-8](https://doi.org/10.1016/S0006-8993(03)03168-8).
- Cerf-Ducastel, B., & Murphy, C. (2009). Age-related differences in the neural substrates of cross-modal olfactory recognition memory: an fMRI investigation. *Brain research*, *1285*, 88-98. doi: [/10.1016/j.brainres.2009.05.086](https://doi.org/10.1016/j.brainres.2009.05.086).
- Childs, J. L., Thompson, J. L., Lillard, J. S., Berry, T. K., & Drake, M. (2008). Consumer perception of whey and soy protein in meal replacement products. *Journal of Sensory Studies*, *23*(3), 320-339. doi:10.1111/j.1745-459x.2008.00158.x
- Clegg, A., Young, J., Iliffe, S., Rikkert, M. O., & Rockwood, K. (2013). Frailty in elderly people. *The Lancet*, *381*(9868), 752–762. doi: 10.1016/s0140-6736(12)62167-9
- Conti, M. Z., Vicini-Chilovi, B., Riva, M., Zanetti, M., Liberini, P., Padovani, A., & Rozzini, L. (2013). Odor identification deficit predicts clinical conversion from mild cognitive impairment to dementia due to Alzheimer's disease. *Archives of Clinical Neuropsychology*, *28*(5), 391-399. doi:10.1093/arclin/act032
- Cox, N. J., Morrison, L., Ibrahim, K., Robinson, S. M., Sayer, A. A., & Roberts, H. C. (2020). New horizons in appetite and the anorexia of ageing. *Age and Ageing*. doi: 10.1093/ageing/afaa014
- Delwiche, J. F. (2012). You eat with your eyes first. *Physiology & Behavior*, *107*(4), 502-504. doi: [10.1016/j.physbeh.2012.07.007](https://doi.org/10.1016/j.physbeh.2012.07.007).
- Doets, E. L., & Kremer, S. (2016). The silver sensory experience – A review of senior consumers' food perception, liking and intake. *Food Quality and Preference*, *48*, 316–332. doi: 10.1016/j.foodqual.2015.08.010
- Doty, R. L. (2018). Age-related deficits in taste and smell. *Otolaryngologic Clinics of North America*, *51*(4), 815–825. doi: 10.1016/j.otc.2018.03.014

- Ekelund, L., Fernqvist, F., & Tjärnemo, H. (2007). Consumer preferences for domestic and organically labelled vegetables in Sweden. *Acta Agriculturae Scandinavica, Section C — Food Economics*, 4(4), 229–236. doi: 10.1080/16507540701800665
- Esquivel, M. K. (2017). Nutritional assessment and intervention to prevent and treat malnutrition for fall risk reduction in elderly populations. *American Journal of Lifestyle Medicine*, 12(2), 107–112. doi: 10.1177/1559827617742847
- Essed, N. H., Kleikers, S., Staveren, W. A. V., Kok, F. J., & Graaf, C. D. (2009). No effect on intake and liking of soup enhanced with mono-sodium glutamate and celery powder among elderly people with olfactory and/or gustatory loss. *International Journal of Food Sciences and Nutrition*, 60(sup5), 143–154. doi: 10.1080/09637480802710216
- Essed, N. H., Staveren, W. A. V., Kok, F. J., & Graaf, C. D. (2007). No effect of 16 weeks flavor enhancement on dietary intake and nutritional status of nursing home elderly. *Appetite*, 48(1), 29–36. doi: 10.1016/j.appet.2006.06.002
- Evers, M. M., & Marin, D. B. (2002). Mood disorders: Effective management of major depressive disorder in the geriatric patient. *Geriatrics*, 57(10), 36–41.
- Faulkner, G. P., Pourshahidi, L. K., Wallace, J. M. W., Kerr, M. A., Mccaffrey, T. A., & Livingstone, M. B. E. (2013). Perceived ‘healthiness’ of foods can influence consumers’ estimations of energy density and appropriate portion size. *International Journal of Obesity*, 38(1), 106–112. doi: 10.1038/ijo.2013.69
- Feng, P., Huang, L., & Wang, H. (2014) Taste bud homeostasis in health, disease, and ageing. *Chemical senses*, 39(1), 3.
- Fischer, M. E., Cruickshanks, K. J., Schubert, C. R., Pinto, A., Klein, R., Pankratz, N., ... Huang, G. H. (2013). Factors related to fungiform papillae density: The Beaver Dam offspring study. *Chemical Senses*, 38(8), 669–677. doi:10.1093/chemse/bjt033.
- Forde, C., & Delahunty, C. (2004). Understanding the role cross-modal sensory interactions play in food acceptability in younger and older consumers. *Food Quality and Preference*, 15(7-8), 715–727. doi: 10.1016/j.foodqual.2003.12.008
- Fukunaga, A., Uematsu, H., & Sugimoto, K. (2005). Influences of aging on taste perception and oral somatic sensation. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences*, 60(1), 109–113. doi: 10.1093/gerona/60.1.109

- Griep, M., Mets, T., & Massart, D. (1997). Different effects of flavour amplification of nutrient dense foods on preference and consumption in young and elderly subjects. *Food Quality and Preference*, 8(2), 151-156. doi:10.1016/s0950-3293(96)00043-2
- Johansen, S. B., Næs, T., Øyaas, J., & Hersleth, M. (2010). Acceptance of calorie-reduced yoghurt: Effects of sensory characteristics and product information. *Food Quality and Preference*, 21(1), 13–21. doi: 10.1016/j.foodqual.2009.07.003
- Johnson, V. L., & Hunter, D. J. (2014). The epidemiology of osteoarthritis. *Best Practice & Research in Clinical Rheumatology*, 28(1), 5-15. doi:10.1016/j.berh.2014.01.004
- Joint FAO/WHO/UNU Expert Consultation. (2007). Protein and amino acid requirements in human nutrition: Report of a joint FAO/WHO/UNU expert consultation. [https://www.who.int/nutrition/publications/nutrientrequirements/WHO\\_TRS\\_935/en/](https://www.who.int/nutrition/publications/nutrientrequirements/WHO_TRS_935/en/)
- Joussain, P., Thevenet, M., Rouby, C., & Bensafi, M. (2013). Effect of aging on hedonic appreciation of pleasant and unpleasant odors. *PLoS ONE*, 8(4), 7. doi: 10.1371/journal.pone.0061376.
- Kaneda, H., Maeshima, K., Goto, N., Kobayakawa, T., Ayabe-Kanamura, S., & Saito, S. (2000). Decline in taste and odor discrimination abilities with age, and relationship between gustation and olfaction. *Chemical Senses*, 25(3), 331–337. doi: 10.1093/chemse/25.3.331
- Konstantinidis, I., Hummel, T., & Larsson, M. (2006). Identification of unpleasant odors is independent of age. *Archives of Clinical Neuropsychology*, 21(7), 615-621. doi: 10.1016/j.acn.2006.05.006.
- Koskinen, S., Kälviäinen, N., & Tuorila, H. (2003). Flavor enhancement as a tool for increasing pleasantness and intake of a snack product among the elderly. *Appetite*, 41(1), 87–96. doi: 10.1016/s0195-6663(03)00054-0
- Kremer, S., Bult, J. H., Mojet, J., & Kroeze, J. H. (2007). Food perception with age and its relationship to pleasantness. *Chemical Senses*, 32(6), 591–602. doi: 10.1093/chemse/bjm028
- Kremer, S., Mojet, J., & Kroeze, J. H. (2005). Perception of texture and flavor in soups by elderly and young subjects. *Journal of Texture Studies*, 36(3), 255–272. doi: 10.1111/j.1745-4603.2005.00015.x
- Krystallis, A., Maglaras, G., & Mamalis, S. (2008). Motivations and cognitive structures of consumers in their purchasing of functional foods. *Food Quality and Preference*, 19(6), 525–538. doi: 10.1016/j.foodqual.2007.12.005

- Li, C., Lin, L., Sui, F., Wang, Z., Huo, H., Dai, L., & Jiang, T. (2014). Chemistry and pharmacology of *Siraitia grosvenorii*: A review. *Chinese Journal of Natural Medicines*, *12*(2), 89-102. doi:10.1016/s1875-5364(14)60015-7
- Lidón, I., Rebollar, R., Gil-Pérez, I., Martín, J., & Vicente-Villardón, J. L. (2018). The influence the image of the product shown on food packaging labels has on product perception during tasting: Effects and gender differences. *Packaging Technology and Science*, *31*(10), 689-697. doi:10.1002/pts.2407
- Lorieau, L., Septier, C., Laguerre, A., Roux, L. L., Hazart, E., Ligneul, A., . . . Labouré, H. (2018). Bolus quality and food comfortability of model cheeses for the elderly as influenced by their texture. *Food Research International*, *111*, 31-38. doi:10.1016/j.foodres.2018.05.013
- Marty, E., Liu, Y., Samuel, A., Or, O., & Lane, J. (2017). A review of sarcopenia: Enhancing awareness of an increasingly prevalent disease. *Bone*, *105*, 276–286. doi: 10.1016/j.bone.2017.09.008
- Mccrickerd, K., Tang, C. S., & Forde, C. G. (2020). The independent and combined impact of front-of-pack labelling and sensory quality on calorie estimations and portion selection of commercial food products. *Food Quality and Preference*, *79*, 103766. doi:10.1016/j.foodqual.2019.103766
- Mela, D. J. (1999). Food choice and intake: The human factor. *Proceedings of the Nutrition Society*, *58*(3), 513-521. doi:10.1017/s0029665199000683
- Mela, D. J. (2000). Why do we like what we like? *Journal of the Science of Food and Agriculture*, *81*(1), 10-16. doi:10.1002/1097-0010(20010101)81:13.0.co;2-d
- Mela, D. J. (2006). Eating for pleasure or just wanting to eat? Reconsidering sensory hedonic responses as a driver of obesity. *Appetite*, *47*(1), 10-17. doi:10.1016/j.appet.2006.02.006
- Methven, L., Allen, V. J., Withers, C. A. & Gosney, M. A. (2012). Ageing and taste. *The Proceedings of the Nutrition Society*, *71*(4), 556-565. doi: 10.1017/S0029665112000742.
- Mintel. (2019). Marketing to Baby Boomers--U.S.-- July 2019. “Full Report” Retrieved September 16, 2019 from Mintel Reports database. URL: <https://store.mintel.com/us-marketing-to-baby-boomers-market-report>
- Mintel. (2019). Marketing to Millennials--U.S.-- June 2019. “Full Report” Retrieved September 16, 2019 from Mintel Reports database. URL: <https://store.mintel.com/us-marketing-to-millennials-market-report>

- Mojet, J., Christ-Hazelhof, E., & Heidema, J. (2005). Taste perception with age: pleasantness and its relationships with threshold sensitivity and supra-threshold intensity of five taste qualities. *Food Quality and Preference*, *16*(5), 413–423. doi: 10.1016/j.foodqual.2004.08.001
- Mojet, J., Heidema, J., Christ-Hazelhof, E. (2004). Effect of concentration on taste-taste interactions in foods for elderly and young subjects. *Chemical Senses*, *29*(8), 671–681. doi: 10.1093/chemse/bjh070
- Morley, J. E., & Kraenzle, D. (1994). Causes of weight loss in a community nursing home. *Journal of the American Geriatrics Society*, *42*(6), 583-585. doi:10.1111/j.1532-5415.1994.tb06853.x
- Morris, C., Beresford, P., & Hirst, C. (2018). Impact of food retailer branding on expectation generation and liking. *Journal of Sensory Studies*, *33*(2). doi:10.1111/joss.12322
- Nguyen, H., & Wismer, W. V. (2019). A comparison of sensory attribute profiles and liking between regular and sodium-reduced food products. *Food Research International*, *123*, 631-641. doi:10.1016/j.foodres.2019.05.037
- Okamoto, M., & Dan, I. (2013). Extrinsic information influences taste and flavor perception: A review from psychological and neuroimaging perspectives. *Seminars in Cell & Developmental Biology*, *24*(3), 247–255. doi: 10.1016/j.semcdb.2012.11.001
- Pathai, S., Shiels, P. G., Lawn, S. D., Cook, C., & Gilert, C. (2013). The eye as a model of ageing in translational research – Molecular, epigenetic, and clinical aspects. *Ageing Research Reviews*, *12*(2), 490-508. doi: 10.1016/j.arr.2012.11.002.
- Pinto, J. M., Wroblewski, K. E., Kern, D. W., Schumm, L. P., & McClintock, M. K. (2015). The rate of age-related olfactory decline among the general population of older U.S. adults. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences*, *70*(11), 1435–1441. doi: 10.1093/gerona/glv072
- Piqueras-Fiszman, B., & Spence, C. (2015). Sensory expectations based on product-extrinsic food cues: An interdisciplinary review of the empirical evidence and theoretical accounts. *Food Quality and Preference*, *40*, 165-179. doi:10.1016/j.foodqual.2014.09.013
- Razak PA, Richard KM, Thankachan RP, Hafiz KA, Kumar KN, Sameer KM. Geriatric oral health: A review article. *J Int Oral Health*. 2014;6(6):110–116.
- Reis, F., Alcaire, F., Deliza, R., & Ares, G. (2017). The role of information on consumer sensory, hedonic and wellbeing perception of sugar-reduced products: Case study with

- orange/pomegranate juice. *Food Quality and Preference*, 62, 227-236.  
doi:10.1016/j.foodqual.2017.06.005
- Rosenbloom, C. A., & Whittington, F. J. (1993). The effects of bereavement on eating behaviors and nutrient intakes in elderly widowed persons. *Journal of Gerontology*, 48(4).  
doi:10.1093/geronj/48.4.s223
- Santagiuliana, M., Irene A. F. Van Den Hoek, Stieger, M., Scholten, E., & Piqueras-Fiszman, B. (2019). As good as expected? How consumer expectations and addition of vegetable pieces to soups influence sensory perception and liking. *Food & Function*, 10(2), 665-680.  
doi:10.1039/c8fo01800f
- Schab, F. R. (1990). Odors and the remembrance of things past. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 16(4), 648-655. doi:10.1037/0278-7393.16.4.648
- Schiffman, S. S., Crumbliss, A. L., Warwick, Z. S., & Graham, B. G. (1990). Thresholds for sodium salts in young and elderly human subjects: correlation with molar conductivity of anion. *Chemical Senses*, 15(6), 671-678. doi: 10.1093/chemse/15.6.671
- Schiffman, S. S., Gatlin, L. A., Frey, A. E., Heiman, S. A., Stagner, W. C., & Cooper, D. C. (1994). Taste perception of bitter compounds in young and elderly persons: Relation to lipophilicity of bitter compounds. *Neurobiology of Aging*, 15(6), 743-750. doi: 10.1016/0197-4580(94)90057-4
- Schiffman, S. S., Sattely-Miller, E. A., Zimmerman, I. A., Graham, B. G., & Erickson, R. P. (1994). Taste perception of monosodium glutamate (MSG) in foods in young and elderly subjects. *Physiology & Behavior*, 56(2), 265-275. doi: 10.1016/0031-9384(94)90194-5
- Seiberling, K. A., & Conley, D. B. (2004). Aging and olfactory and taste function. *Otolaryngologic Clinics of North America*, 37(6), 1209-1228.
- Shimizu, Y. (1997). A histomorphometric study of the age-related changes of the human taste buds in circumvallate papillae. *Oral Medical Pathology*, 2, 17-24.
- Ship, J. A., Pearson, J. D., Cruise, L. J., Brant, L. J., & Metter, E. J. (1996). Longitudinal changes in smell identification. *Journal of Gerontology*, 51a(2), M86-M91. doi: 10.1093/gerona/51a.2.m86
- Spence, C., & Shankar, M. U. (2010). The influence of auditory cues on the perception of, and responses to, food and drink. *Journal of Sensory Studies*, 25(3), 406-430. doi: 10.1111/j.1745-459X.2009.00267.x.

- Stahlman, L. B., Garcia, J. M., Chambers, E., Smit, A. B., Hoag, L., & Chambers, D. H. (2001). Perceptual ratings for pureed and molded peaches for individuals with and without impaired swallowing. *Dysphagia*, *16*(4), 254–262. doi: 10.1007/s00455-001-0084-6
- Stahlman, L. B., Garcia, J. M., Hakel, M., & Iv, E. C. (2000). Comparison ratings of pureed versus molded fruits: Preliminary results. *Dysphagia*, *15*(1), 2–5. doi: 10.1007/s004559910002
- Stangierski, J., & Kawecka, A. (2019). An evaluation of the mechanical and sensory characteristics of selected foodstuffs for senior citizens. *Acta Scientiarum Polonorum Technologia Alimentaria*, *18*(3), 305–315. doi: 10.17306/j.afs.0655
- Stelt, A. J. V. D., Mehring, P., Corbier, C., Eijnatten, E. J. V., & Withers, C. (2020). A “mouthfeel wheel” terminology for communicating the mouthfeel attributes of medical nutrition products (MNP). *Food Quality and Preference*, *80*, 103822. doi: 10.1016/j.foodqual.2019.103822
- Stenholm, S., Harris, T. B., Rantanen, T., Visser, M., Kritchevsky, S. B., & Ferrucci, L. (2008). Sarcopenic obesity: definition, cause and consequences. *Current Opinion in Clinical Nutrition and Metabolic Care*, *11*(6), 693–700. doi: 10.1097/mco.0b013e328312c37d
- Stinton, N., Atif, M. A., Barkat, N., & Doty, R. L. (2010). Influence of smell loss on taste function. *Behavioral Neuroscience*, *124*(2), 256–264. doi: 10.1037/a0018766
- Torrico, D. D., Fuentes, S., Viejo, C. G., Ashman, H., & Dunshea, F. R. (2019). Cross-cultural effects of food product familiarity on sensory acceptability and non-invasive physiological responses of consumers. *Food Research International*, *115*, 439-450. doi:10.1016/j.foodres.2018.10.054
- Toussaint, N., Roon, M. D., J. P. C. M. Van Campen, Kremer, S., & Boesveldt, S. (2015). Loss of olfactory function and nutritional status in vital older adults and geriatric patients. *Chemical Senses*, *40*(3), 197–203. doi: 10.1093/chemse/bju113
- Urala, N., & Lähteenmäki, L. (2004). Attitudes behind consumers willingness to use functional foods. *Food Quality and Preference*, *15*(7-8), 793–803. doi: 10.1016/j.foodqual.2004.02.008
- Urala, N., & Lähteenmäki, L. (2007). Consumers’ changing attitudes towards functional foods. *Food Quality and Preference*, *18*(1), 1–12. doi: 10.1016/j.foodqual.2005.06.007
- Valenzuela, R., Ponce, J. A., Morales-Figueroa, G. G., Muro, A., Carreón, R., & Aleman-Mateo, H. (2013). Insufficient amounts and inadequate distribution of dietary protein intake in apparently healthy older adults in a developing country: Implications for dietary strategies to prevent sarcopenia. *Clinical Interventions in Aging*, *11*, 1143-1148. doi:10.2147/cia.s49810

- Vandenberghe-Descamps, M., Sulmont-Rossé, C., Septier, C., Feron, G., & Labouré, H. (2017). Using food comfortability to compare foods sensory characteristics expectations of elderly people with or without oral health problems. *Journal of Texture Studies*, 48(4), 280–287. doi: 10.1111/jtxs.12250
- Waskul, D. D., Vannini, P., & Wilson, J. (2009). The aroma of recollection: olfaction, nostalgia, and the shaping of the sensuous self. *The Senses and Society*, 4(1), 5-22. doi:10.2752/174589309x388546
- Zampini, M., & Spence, C. (2004). The role of auditory cues in modulating the perceived crispness and staleness of potato chips. *Journal of Sensory Studies*, 19(5), 347-363. doi: 10.1111/j.1745-459x.2004.080403.x.
- Zampini, M., & Spence, C. (2012). Assessing the role of visual and auditory cues in multisensory perception of flavor. In M. M. Murray & M. T. Wallace (Eds.), *The neural bases of multisensory processes*. Boca Raton (FL): CRC Press.