Age-related changes in oral and nasal physiology and their significance in aroma release and perception

SOPHIE LESTER[1], M. Taylor[2], C. Corbier[3], L. Cornacchia[3] and Ian Fisk[1]
[1] *University of Nottingham, Division of Food Sciences, Nottingham, UK.*
[2] *University of Nottingham, Faculty of Medicine & Health Sciences, Nottingham, UK.*
[3] *Nutricia Research, Uppsalalaan 12, 3584 CT Utrecht, The Netherlands*

Abstract

With aging comes many physiological changes, including those in the oral and nasal cavity, such as impaired olfactory function, reduced salivary flow and compromised dental status and function [1-3]. These changes may impact on aroma release and flavour perception, and subsequently the enjoyment of foods, leading a risk of undernutrition. This review aimed to summarise current literature on how olfaction is affected by aging, the major physiological parameter in flavour perception. With the worldwide projected increase in the older population, the economic and social burden of undernutrition is expected to be severe. Tackling this issue is of interest to both clinical practice and industry, as there is potential for new products to be developed which meet the needs and sensory preferences of this specific, increasing population.

Introduction

Due to socioeconomic development people are living longer than ever [4]. For example, somebody born in Japan in 2015 was projected to live until 90 years old, this is compared to only 83 years if born in 1985 [4]. Although extra years are added to life, unavoidable changes in sensory capacity may reduce functionality and life quality. It is well documented that aging is associated with a decline in both vision and hearing[4]; however, a lesser acknowledged sensory impairment, is the sense of olfaction.

Discussion

Importance of olfaction

Olfactory impairments have been proposed to be a key contributor in the aetiology of "anorexia of aging" [5, 6] a term which alludes to the high prevalence of undernutrition within the older adult population. The "anorexia of aging" leads to multifaceted clinical conditions, such as frailty and sarcopenia, which are common among frail older persons, and are related to many comorbidities and ultimately an increased risk of mortality [5].

Olfaction is a key contributor to the anorexia of aging due to the impact it may have on hunger and appetite [7] and on reducing nutritional quality and altering dietary habits [8]. For example, Duffy *et al.* (1995) [9] found that older women (aged 65 to 93 years) with olfactory dysfunction had lower interest in food-related activities (i.e. cooking) and Aschenbrenner *et al.* (2008) [10] found that more than one-third of patients with olfactory loss reported changes in their social food-related activities. In terms of altered nutritional quality, Duffy *et al.* (1995) [9] found that olfactory impairments led to a lower preference for foods with predominant sour/bitter taste such as fruits and vegetables, and higher intake of sweets. Such evidence is supported by the work of Griep *et al.* (1996) [11] who found that older individuals with olfactory impairments had lower nutrient intake levels than older individuals with good odour perception. One recent study has suggested that community dwelling older adults with impairments in sensory perception, including olfaction, are at a greater risk of frailty [12] due to decreased appetite and food intake. It

B. Siegmund & E. Leitner (Eds): Flavour Sci., 2018, Verlag der Technischen Universität Graz
DOI: 10.3217/978-3-85125-593-5-33, CC BY-NC-ND 4.0

has been suggested that weight loss is more frequent in individuals with olfactory impairments [8, 10, 13, 14]; Gopinath *et al.* (2012) [14] found that BMI was significantly lower in participants with, than without, olfactory impairment. Weight loss is a significant problem in the population of older adults as it can lead to muscle wasting, decreased immunocompetence and increased rate of complications, along with being highly predictive of morbidity and mortality [15]. Thus olfactory impairments have been proposed to be predictive of overall mortality, over a 5 year period [14]. Schiffman and Graham (2000) [16] also drew attention to how undernutrition itself may be a risk factor for olfactory impairments as deficiencies in the B Vitamins Niacin and Vitamin B12 and Zinc impair olfactory function [14], so it is easy to understand how undernutrition may become exacerbated and maintained.

Prevalence of age-related olfactory impairment

The prevalence of impaired olfactory function in the older adult population is high. Using a smell identification test, Doty *et al.* (1984) [17] conducted a cross-sectional study in 1955 individuals and found that 60% of those aged 65-80 were experiencing major olfactory impairments. More recently, Murphy *et al,* (2002) [18] conducted a population-based study with 2491 individuals aged 57-93 years. They found the prevalence of olfactory impairment to be 24.9% and also that the prevalence increases with age; within the population of 80- to 97-year-olds, 62.5% were experiencing olfactory impairments.

Causes of age-related olfactory impairment

The cause of olfactory impairments is likely to be multi-factorial, involving age-related alterations within the nose, olfactory epithelium, olfactory bulb and higher levels of the brain that receive olfactory input [1, 19, 20]. The complex causes of age-related olfactory impairment are discussed in detail in the review by Doty and Kamath, (2014) who summarised potential contributing factors to be: altered nasal engorgement and airflow, increased propensity for nasal disease, cumulative damage to the olfactory epithelium from viral and other environmental insults, decrements in mucosal metabolizing enzymes, ossification of cribriform plate foramina, loss of selectivity of receptor cells to odorants and changes in neurotransmitter and neuromodulator systems. A potential genetic contribution to odour identification ability has also been identified [21, 22].

There is a strong association between olfactory impairment and age-related neurodegenerative disease, such as Alzheimer's and Parkinson's disease. Olfactory impairments can be an early symptom of these diseases, which Doty and Kamath, (2014) [1] proposed to be due to expression of aberrant proteins. The significance of these proteins was shown by Wilson *et al,* (2007) [23], who found inverse correlations between Brief Smell Identification Test (B-SIT) scores obtained before death and the post-mortem density of neurofibrillary tangles. In another study, Wilson *et al,* (2011) [24] found an inverse relationship between B-SIT scores and post-mortem measures of Lewy bodies in limbic and cortical brain regions. This evidence suggests that olfactory impairment in older adults in not confined to structural changes within the nose, but its aetiology is likely to involve higher brain structures.

Lastly, the influence of medications should be taken into account. Many drugs used to treat age-related conditions, such as antihypertensive medications and statins, are known to affect both taste and smell [20]. A comprehensive discussion of these medications and diseases can be found in Schiffman and Zervakis (2002) [20] who states that older adults experience an exaggerated burden of chemosensory disorders from these medications, compared to younger individuals.

Aroma- specificity of age-related olfactory impairment

While older adults experience an impairment in their olfactory function, only a few studies have investigated how their perception of single aroma compounds changes with aging. In a large survey involving 1.2 million National Geographic readers, Wysocki and Gilbert (1989) [25] reported differences in the rate of age-related olfactory loss to six odorants. More recently, Seow *et al*, (2016) [26] conducted a study using The Specific Sensitivity test involving 281 participants of various age groups. They tested the identification rates and detection thresholds of 10 odorants, with various chemical and sensory properties, and found large differences in detection thresholds for some odorants, between age groups. For example, participants in their 70s had a detection threshold 179 times higher than the young for the rose-like aroma compound phenylethyl alcohol, whereas for the onion-like aroma compound 2-methyloxolane-3-thiol, the threshold was only 3 times higher. Interestingly, they also found that the older subjects had higher identification rates if they rated the odorants as pleasant. This is supported by Wysocki and Gilbert (1989) [25] who found no age effect for the intensity rating of galaxolide (which may be considered a pleasant aroma), whereas a 26% age decline was observed for methanethiol (which could be considered an unpleasant aroma). These findings are is in contrast to Konstantindis *et al*, (2006) [27] who found that, unlike pleasant odours, unpleasant odours were not sensitive to age-related olfactory loss.

In an effort to explain the physiological phenomenon of aroma-specific age-related loss, Sinding *et al*, (2014) [28] investigated if there was a difference in age-related odour perception between aroma molecules with heavy and light molecular weights, based on the idea that the molecules would bind differently to olfactory receptors. They found that older adults experience olfactory loss more specific to heavier molecules, suggesting that aroma-specific age-related loss bears connection to the molecular structure of individual aroma molecules.

Considering these findings on age-related aroma-specific sensory loss, it is reasonable to conclude that it is not simply the case that older adults perceive flavour at a weaker intensity, it is likely that their overall flavour perception becomes distorted as the contribution made by individual aroma compounds to a flavour mixture is altered.

Previous food-based aroma strategies to counteract olfactory changes

To endeavour to combat the effects of olfactory impairments in older adults, a reasonable response undertaken is to modify the aroma in food in an effort to counteract impairments, and ultimately improve food liking and intake. Many studies have investigated this, however, results have not been consistently successful. For example, Koskinen, *et al*, (2003) [29] heightened the aroma in a yogurt-like fermented oat bran *product and found that older adults liking and intake of the product was lower, when* compared with the regular product. Considering that olfactory loss is aroma-specific [25-27], heightening of aroma may have distorted flavour perception [26], and may explain why some panellists reported an “artificial flavour”.

Future approaches and conclusion

In order to combat age-related olfactory impairments, more tailored aroma-modification strategies are needed. Seow *et al*, (2016) [26] stated that, in order to design targeted remedies for the effects of chemosensory losses (including olfaction), it is imperative to first gain insight on the extent of olfactory loss to specific single aroma compounds. Developing foods which meet the sensory needs of the aging population is a challenging and complex task, but considering the social and economic burden of undernutrition, it is a vital challenge to overcome.

References

1. Doty RL, Kamath V (2014) Applied Olfactory Cognition 5:213-232
2. Martin-Harris B, Brodsky MB, Michel Y, Ford CL, Walters B, Heffner J (2005) Archives of Otolaryngology–Head & Neck Surgery 131:762-770
3. Vandenberghe-Descamps M, Labouré H, Prot A, Septier C, Tournier C, Feron G, Sulmont-Rossé C (2016) Journal of Texture Studies 47(4):353-360
4. WHO (2015) World report on ageing and health. World Health Organization
5. Landi F, Calvani R, Tosato M, Martone AM, Ortolani E, Savera G, Sisto A, Marzetti E (2016) Nutrients 8:69
6. Wysokiński A, Sobów T, Kłoszewska I, Kostka T (2015) Age 37:81
7. de Jong N, Mulder I, de Graaf C, van Staveren WA (1999) Journals of Gerontology Series A: Biomedical Sciences and Medical Sciences 54:B324-B331
8. Mattes RD, Cowart BJ, Schiavo MA, Arnold C, Garrison B, Kare MR, Lowry LD (1990) The American journal of clinical nutrition 51:233-240
9. Duffy VB, Backstrand JR, Ferris AM (1995) Journal of the American Dietetic Association 95:879-884
10. Aschenbrenner K, Hummel C, Teszmer K, Krone F, Ishimaru T, Seo H-S, Hummel T (2008) The Laryngoscope 118:135-144
11. Griep M, Verleye G, Franck A, Collys K, Mets T, Massart D (1996) European journal of clinical nutrition 50:816-825
12. Somekawa S, Mine T, Ono K, Hayashi N, Obuchi S, Yoshida H, Kawai H, Fujiwara Y, Hirano H, Kojima M (2017) The journal of nutrition, health & aging 21:710-714
13. Frasnelli J, Landis B, Heilmann S, Hauswald B, Hüttenbrink K, Lacroix J, Leopold D, Hummel T (2004) European Archives of Oto-Rhino-Laryngology and Head & Neck 261:411-415
14. Gopinath B, Anstey KJ, Kifley A, Mitchell P (2012) Maturitas 72:50-55
15. Alibhai SM, Greenwood C, Payette H (2005) Canadian Medical Association Journal 172:773-780
16. Schiffman S, Graham B (2000) European Journal of Clinical Nutrition 54:S54
17. Doty RL, Shaman P, Applebaum SL, Giberson R, Siksorski L, Rosenberg L (1984) Science 226:1441-1443
18. Murphy C, Schubert CR, Cruickshanks KJ, Klein BE, Klein R, Nondahl DM (2002) Jama 288:2307-2312
19. Attems J, Walker L, Jellinger KA (2015) Gerontology 61:485-490
20. Schiffman SS, Zervakis J (2002) Advances in food and nutrition research 44:247-346
21. Calhoun-Haney R, Murphy C (2005) Brain and cognition 58:178-182
22. Hedner M, Nilsson L-G, Olofsson JK, Bergman O, Eriksson E, Nyberg L, Larsson M (2010) Frontiers in aging neuroscience 2
23. Wilson RS, Arnold SE, Schneider JA, Tang Y, Bennett DA (2007) Journal of Neurology, Neurosurgery & Psychiatry 78:30-35
24. Wilson RS, Yu L, Schneider JA, Arnold SE, Buchman AS, Bennett DA (2011) Chemical senses 36:367-373
25. Wysocki CJ, Gilbert AN (1989) Annals of the New York Academy of Sciences 561:12-28
26. Seow Y-X, Ong PKC, Huang D (2016) Chemical Senses 41:487-495
27. Konstantinidis I, Hummel T, Larsson M (2006) Archives of Clinical Neuropsychology 21:615-621
28. Sinding C, Puschmann L, Hummel T (2014) Chemical senses:bju004
29. Koskinen S, Kälviäinen N, Tuorila H (2003) Appetite 41:87-96