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INFLUENCE OF CHEMOSENSORY PERFORMANCE ON FLAVOR PERCEPTION
AND FOOD ACCEPTANCE OF THE ELDERLY

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ACADEMIC DISSERTATION

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ABSTRACT

The role of chemical senses, especially olfaction, on flavor perception and food acceptance of the elderly was investigated. Detailed aims were to examine the effectiveness of flavor enhancement in improving food acceptance of the elderly and the ability of olfactory tests to predict subject's food odor and flavor perception.

The effects of age group and chemosensory performance on sensory and hedonic responses of the young and elderly were studied in flavored yogurts varying in odor, taste, and trigeminal stimuli, and in whey drinks, grape juice, and yogurt varying in odor stimuli. The effect of flavor enhancement on liking and intake in repeated use was studied in 1) a yogurt-like oat bran product with regular and heightened currant aroma concentrations (young and elderly) and 2) regular smoked hams and smoked hams with added smoke aroma or pepper mix (elderly only). The provision of variety was examined as an alternative means of boosting food intakes of elderly. The taste and trigeminal acuities of the subjects were examined in one study, and olfactory acuity in all studies. Methodological aspects of olfactory performance were examined by comparing different olfactory tests and their correspondence with ortho- and retronasal intensity ratings in anosmic, hyposmic, and normosmic subjects. The ability of one olfactory test to predict ortho- and retronasal intensity ratings of aqueous solutions, semi-solid food, and beverages among young and elderly subjects was also examined.

The olfactory tests were considered to be valid for clinical evaluation of olfactory capabilities. The predictive ability of these tests was moderate when it came to suprathreshold orthonasal ratings and retronasal ratings for simple aqueous solutions, but poor for suprathreshold retronasal intensity ratings of real food and beverages. Chemosensory performance of the elderly affected sensory as well as hedonic ratings, leading to altered food flavor perception. In home-use studies, the pleasantness ratings of the elderly for the two oat bran samples merged because of increased liking for the stronger aroma. Such an effect was not observed in ratings for smoked hams. Increasing age was related to disregard for intensified flavor in hedonic responses, while olfactory performance was not associated with preference. For these products, flavor enhancement did not increase elderly people's intakes, although the total consumption of smoked hams, regardless of the flavor level, was higher in subjects with olfactory deficits.

In conclusion, the young and elderly differed in their flavor perception, but this was not strongly related to their food preferences. As the relationship between performance on standardized olfactory tests and flavor perception of food/beverages was rather weak, the benefit of using such tests in food acceptance studies is debatable. Flavor enhancement had a very limited effect on increasing food liking and intakes of the elderly.

PREFACE

This study was carried out in Department of Food Technology, University of Helsinki during the years 2001-2005. Combining traditional sensory science approach with special interest on the elderly proved to be a challenging, but also a very fascinating project. When conducting a field study, a researcher must familiarize herself with the natural living environment of the subjects – my personal experiences during these years vary from singing religious songs in a senior club to receiving tips of growing herbal plants and using them in cooking.

This study was financially supported by following organizations: the Finnish Graduate School Program ‘Applied Bioscience – Bioengineering, Food & Nutrition, Environment’ (ABS), the European Commission’s Quality of Life Fifth Framework Program QLK1-CT 1999-00010: “Healthy ageing: how changes in sensory physiology, sensory psychology, and socio-cognitive factors influence food choice”, and the ELITE research program of Finnish National Technology Agency (TEKES), as part of the project “Innovation in foods: Consumer-oriented product development”. Their support is gratefully acknowledged.

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Helsinki, March 2005

Sari Koskinen

LIST OF ORIGINAL PUBLICATIONS

This thesis is based on the following original articles referred to in the text by Roman numerals I-V.

- I Koskinen, S., Kälviäinen, N., and Tuorila, H. 2003. Perception of chemosensory stimuli and related responses to flavored yogurts in the young and elderly. *Food Quality and Preference* 14: 623-635.
- II Koskinen, S., Kälviäinen, N., and Tuorila, H. 2003. Flavor enhancement as a tool for increasing pleasantness and intake of a snack product among the elderly. *Appetite* 41: 87-96.
- III Koskinen, S., Vento, S., Malmberg, H., and Tuorila, H. 2004. Correspondence between three olfactory tests and suprathreshold odor intensity ratings. *Acta Oto-Laryngologica* 124: 1072-1077.
- IV Koskinen, S. and Tuorila, H. Performance on an odor detection and identification test as a predictor of ortho- and retronasal odor intensity ratings in the young and elderly. *Food Quality and Preference*, in press.
- V Koskinen, S., Nenonen, A., and Tuorila, H. Intakes of cold cuts in the elderly are predicted by olfaction and mood, but not by flavor type or intensity of the products. Submitted to *Physiology & Behavior*.

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RESEARCH INPUT AND AUTHORSHIP OF ARTICLES (I-V)

This thesis is a summary of the research reported in the five (I-V) appended articles. The research input and authorship of the articles are as follows:

- I *Koskinen, S., Kälviäinen, N., and Tuorila, H. 2003. Perception of chemosensory stimuli and related responses to flavored yogurts in the young and elderly. Food Quality and Preference 14: 623-635.*

The planning of this study as well as the data analysis were carried out by all three authors. The experimental study, including all empirical work and preparation of the manuscript was carried out by M.Sc. Sari Koskinen. The study was supervised by Dr. Niina Kälviäinen and Prof. Hely Tuorila, both of whom also participated in writing of the manuscript by giving comments and suggestions.

- II *Koskinen, S., Kälviäinen, N., and Tuorila, H. 2003. Flavor enhancement as a tool for increasing pleasantness and intake of a snack product among the elderly. Appetite 41: 87-96.*

The planning of this study as well as the data analysis were carried out by M.Sc. Sari Koskinen and Prof. Hely Tuorila. The experimental study, including empirical work and preparation of the manuscript, was carried out by M.Sc. Sari Koskinen. The study was supervised by Dr. Niina Kälviäinen and Prof. Hely Tuorila, both of whom also participated in writing of the manuscript by giving comments and suggestions.

- III *Koskinen, S., Vento, S., Malmberg, H., and Tuorila, H. 2004. Correspondence between three olfactory tests and suprathreshold odor intensity ratings. Acta Oto-Laryngologica 124: 1072-1077.*

The planning of this study was carried out by M.Sc. Sari Koskinen, Dr. Seija Vento and Prof. Hely Tuorila. Data analysis was carried out by M.Sc. Sari Koskinen and Prof. Hely Tuorila. The experimental study, including all empirical work, was carried out by M.Sc. Sari Koskinen and Dr. Seija Vento. Preparation of the manuscript was carried out by M.Sc. Sari Koskinen. The study was supervised by Dr. Seija Vento, Dr. Henrik Malmberg, and Prof. Hely Tuorila, all of whom also participated in writing of the manuscript by giving comments and suggestions.

- IV *Koskinen, S. and Tuorila, H. Performance on an odor detection and identification test as a predictor of ortho- and retronasal odor intensity ratings in the young and elderly. Food Quality and Preference, in press.*

The planning of this study as well as the data analysis were carried out by M.Sc. Sari Koskinen and Prof. Hely Tuorila. The experimental study, including all empirical work and preparation of the manuscript, was carried out by M.Sc. Sari Koskinen. The study was supervised by Prof. Hely Tuorila, who also participated in writing of the manuscript by giving comments and suggestions.

- V *Koskinen, S., Nenonen, A., and Tuorila, H. Intakes of cold cuts in the elderly are predicted by olfaction and mood, but not by flavor type or intensity of the products. Submitted to Physiology & Behavior.*

This study formed the topic for Aino Nenonen's Master's thesis. The planning of the study as well as the data analysis were carried out by M.Sc. Sari Koskinen, Ms. Aino Nenonen and Prof. Hely Tuorila. The experimental study, including all empirical work, was carried out by Ms. Aino Nenonen and M.Sc. Sari Koskinen. Preparation of the manuscript was carried out by M.Sc. Sari Koskinen. The study was supervised by Prof. Hely Tuorila, who also participated in writing of the manuscript by giving comments and suggestions.

1 INTRODUCTION

Age demographics worldwide will change dramatically over the next 25 years. In 2030, there will be more Europeans aged 60 years or beyond than under 20. The food needs of this considerable sector of the population are unknown and have thus been largely neglected. The food industry and food service companies must determine the needs of the aging population to be able to provide foods appreciated by older people (Martin, 2000).

Food choice, as any complex human behavior, is influenced by many interrelating factors. In addition to being determined by physiological or nutritional needs, it is influenced by social and cultural factors (Shepherd, 1989). One well-established factor affecting food acceptance and food choice is the sensory perception of food stimuli. According to Shepherd (1999), the ability to perceive a food's sensory attributes as well as actually liking the food determines whether an individual will consume the item.

Aging often involves a decrease in chemosensory, especially olfactory, abilities, although large interindividual variation does exist (Doty, 1989). From a physiological point of view, one might assume that an individual requires an increase in the intensity of a certain stimulus in direct proportion to any decrease in sensitivity to that stimulus (Murphy et al., 1989). The enhancement of the flavor of foods by adding flavor stimuli is based on this assumption. Elderly people have, in fact, been found to have higher preferred flavor concentrations than the young, but the effect has been stimulus-specific (de Graaf et al., 1994, 1996).

Olfaction contributes notably to food flavor perception since the majority of the flavor of food comes from olfactory stimuli, which are passed from the mouth via the retronasal route to the olfactory epithelium (Taylor and Linforth, 1996). Given the documented declines in chemosensory perception of the elderly, especially in olfaction, it is surprising that older adults do not complain more often about the flavor of their food (Popper and Kroll, 2003). From a psychological viewpoint, one can argue that a person's preferences are entirely acquired and can be continuously adjusted during a gradual decline in chemosensory capabilities over time (Stevens, 1989; Rolls, 1992). Indeed, individuals suffering from a sudden impairment of chemosensory functioning seek higher stimulation of the senses

(Murphy et al., 1989). Age-related weakening of chemosensory capabilities, by contrast, occurs gradually over a long time and may thus go unnoticed. Elderly persons have been found to be largely unaware of their loss of olfaction (Stevens, 1989).

Despite little proof, age-related changes in chemosensory capabilities are believed to cause various detriments in elderly people's lives. They are widely proposed to be a significant factor in the decrease of hedonic value of foods and drinks and the reduction in food intakes, eventually leading to nutritional problems, the most serious of which is known as anorexia of aging (Morley and Silver, 1988; Murphy, 1993, Rolls, 1999). However, to date, no causal relationship between chemosensory impairment and inadequate food/energy/nutrient intakes has been shown. Some studies have, however, reported that malnutrition per se can cause alterations in taste and smell functions (Schiffman, 1997; Davidson et al., 1998). Evidence clearly indicates that elderly people often suffer from olfactory and taste deficits. The impact of these deficits on food acceptance, food choices, food intakes, nutrition, and health remains unclear.

This study aimed at clarifying of the effect of changes in chemical senses, particularly in olfaction, on flavor perception and food acceptance (measured with hedonic ratings and intakes) of the elderly.

2 LITERATURE REVIEW

2.1 Aging population and definition of elderly people

The elderly population is increasing markedly worldwide. Globally, the number of older people, i.e. persons aged 60 years or beyond, has been estimated to rise from 606 million in the year 2000 to 1.9 billion in the year 2050. The absolute increase will be lower in the more developed regions, where the number of older persons is projected to rise from 232 million in 2000 to 394 million in 2050. In the less developed regions, the elderly population is expected to more than quadruple, from 375 million in 2000 to 1.5 billion in 2050. In Europe, aging of the population is most advanced. The proportion of older persons will increase from 20% in 2000 to 35% in 2050. Thus, by this date, there will be 2.4 older persons for every child, and more than one of every three persons will be aged 60 years or over (Report of the United Nations Population Division, 2003).

The dramatic increase in the numbers of the elderly makes this an increasingly important group. At the same time, they constitute a group that is difficult to classify. The age limit used to define the elderly depends on the topic being studied. An arbitrary line is often drawn at age 60. Alternatively, 65 years has also been defined as a limit because this is the usual age of retirement as well as the starting point for greater changes in many functions. According to Hegsted (1989), although many physiologic functions decline with age, it is difficult to determine which of the changes are due to aging per se and which are due to other factors such as inactive lifestyle, illnesses, and medication.

On average, 80% of people over 65 years have one or more diseases. Increasing diversity is a typical phenomenon with age since people age physiologically at different rates (Hegsted, 1989). In the geriatric literature, the terms *successful aging* (Rowe and Kahn, 1987) and *healthy aging* (Simons et al., 2000) have been used to refer to individuals whose aging process is associated with reduced and delayed disability in any types of functions. In other words, successful/healthy aging involves either no diseases or few diseases (Rowe and Kahn, 1987; Simons et al., 2000; Hoffman et al., 1998). Moreover, older individuals' poor overall health status and functional limitations are often associated with an increase in the rate of

chemosensory disorders (Hoffman et al., 1998). Besides physiologic deterioration, aging slows down cognitive processes, affecting many types of functions, including olfactory performance (Murphy, 1985; Larsson et al., 2000; Lehrner et al., 1999).

2.2 Chemical senses and aging

Aging impairs chemosensory perception (odor, taste, chemesthesis), although substantial individual variation does exist. Age-related changes in chemosensory abilities are based on multiple, interacting, and complex anatomic and physiologic factors (Doty, 1989; Schiffman, 1997). The changes may arise from age-related variations in attentional, memory-based, or cognitive functioning, and thus, have no sensory basis at all (Weiffenbach, 1991). Furthermore, a large variation has been found in the chemosensory abilities of older persons, suggesting that the dysfunction is not always related to aging per se. For example, elderly individuals' poor health status and use of medication may severely impair their olfactory performance (Schiffman, 1997).

Olfactory perception tends to decline more than gustatory perception (Murphy, 1993) and is suggested to be relatively uniform across the odorants (Cain and Stevens, 1989). Age-related weakening of taste perception, in turn, seems to be quality-specific (Cowart, 1989; Murphy and Gilmore, 1989), and thus, sensitivity to all taste qualities does not decline at similar rates. Nor does trigeminal sensitivity remain intact throughout the aging process (Laska, 2001; Wysocki et al., 2003). In the following sections, the age-related changes in the three chemosensory modalities (odor, taste, chemesthesis) are examined in more detail.

2.2.1 Olfaction

Olfactory perception occurs via two routes: orthonasal and retronasal. An olfactory stimulus (e.g. aroma) is perceived orthonasally when volatiles are brought into the nasal cavity via the nostrils and sensed by the receptors of the olfactory epithelium. In retronasal perception, the volatiles reach the olfactory epithelium through the nasopharyngeal passage instead of the nostrils (Burdach and Doty, 1987). Thus, olfaction contributes notably to food flavor

perception since flavor mainly consists of olfactory stimuli that are passed from the mouth via the retronasal route to the olfactory epithelium (Taylor, 1996; Taylor and Linforth, 1996).

Olfactory dysfunctions are usually classified into two main categories: decreased olfactory sensitivity (anosmia and hyposmia) and distorted olfactory perception (troposmia, parosmia, and phantosmia) (Leopold and Bartels, 2002). Progressive impairment of odor perception is characteristic of advancing age (Schiffman, 1997; Murphy et al., 2002). Hyposmia tends to become noticeable around 60 years of age, with the losses becoming increasingly severe in individuals older than 70 years. By the age of 80, more than three-fourths of elderly persons have pronounced difficulty in perceiving and identifying odors (Doty et al., 1984; Schiffman and Warwick, 1991). Moreover, age-related diminishment in olfactory capabilities is proposed to be relatively uniform across different odorants (Cain and Stevens, 1989). Wysocki and Gilbert (1989) did, however, show that although a general age-related decrease occurs in the proportion of subjects able to detect odors, the shape of the age-response curves on odor detection varies markedly across odorants, suggesting that age effects on odor detection are heterogeneous.

Elderly persons' impaired ability to smell is revealed in various types of olfactory tasks. Compared with young people, the elderly have higher odor detection thresholds (Cain et al., 1990; Stevens and Cain, 1993; Griep et al., 1995), and impaired ability to identify and discriminate odors (Doty et al., 1984; de Wijk and Cain, 1994). The impairment is also displayed in other basic measures of sensory performance such as suprathreshold intensities and psychophysical functions (Stevens et al., 1984; Stevens and Cain, 1985). Odor identification tasks demand cognitive processing and semantic memory (Murphy et al., 1991; Larsson et al., 2000), which also deteriorate with age. Thus, such tests may exaggerate the true age-related impairment of olfactory capabilities, failing to separate the poor identification ability resulting from memory-based and cognitive deficits from sensory deficits (Murphy, 1985; Weiffenbach, 1991).

Stevens and Cain (1986a) have shown that weakening of olfactory capabilities with age occurs in both orthonasal and retronasal perception. The elderly perceived odor elicited from ethyl butyrate more weakly than did the young, regardless of whether the odor originated

externally through the nostrils (orthonasally) or internally via the mouth (retronasally). In addition to a deterioration in the ability to perceive a broad range of flavors (Stevens and Cain, 1993), aging reduces the ability to discriminate between various suprathreshold odor intensities (Enns and Hornung, 1988; Stevens and Cain, 1993) and flavor intensities (Stevens and Cain, 1993; Duffy et al., 1999; Schiffman and Graham, 2000). Cain et al. (1990) reported measured odor thresholds to correlate significantly with elderly subjects' ability to discriminate flavor.

Duffy et al. (1999) demonstrated that olfactory flavor threshold of elderly women was associated with orthonasally measured odor threshold. Interestingly, some of their subjects had low olfactory flavor sensitivity despite having high orthonasal odor perception ability, suggesting that the elderly may show greater impairment in retronasal perception of olfactory stimulus than in orthonasal perception of odors. By contrast, Stevens and Cain (1986a) proposed that age-related losses in ortho- and retronasal perceptions are roughly equal in magnitude. Heilmann and Hummel (2004), in turn, found significant differences between ortho- and retronasal odor perception on both threshold and suprathreshold levels, indicating that perception of odors via the retronasal route was less effective than via the orthonasal route. According to Heilmann and Hummel (2004), the differences may be related to the functional significance of retronasal odor perception during eating and drinking.

2.2.2 Taste

The majority of studies concerning the effects of age on taste perception show decreased sensitivity of gustation both on threshold (Bartoshuk et al., 1986; Cowart, 1989; Stevens et al., 1995; Mojet et al., 2001) and suprathreshold (Cowart, 1989; Murphy and Gilmore, 1989; Mojet et al., 2003) levels. Although sense of taste weakens with age, the age-related effects are not as profound as for sense of smell (Stevens et al., 1984; Cain and Stevens, 1989; Murphy, 1993; Schiffman, 1993; Kaneda et al., 2000). A possible, although not likely, explanation for age-related decrease in taste ability could be a decrease in the overall number or density of taste buds (Cowart, 1989; Weiffenbach, 1991). Other explanations suggested are aging of the nervous system (Cowart, 1989) and changes in the replacement rate of taste receptors (Weiffenbach, 1991).

Some researchers have found the decrease in taste acuity in the elderly to be stimulus-specific rather than general (Murphy and Gilmore, 1989; Nordin et al., 2003). Weiffenbach et al. (1982) and Cowart (1989), for instance, have shown that advancing age does not diminish sensitivity to sweet taste as much as to other tastes at the suprathreshold level. In line with this, Gilmore and Murphy (1989) reported that the ability to discriminate bitter taste produced by caffeine differed significantly between the young and the elderly, while no significant difference was observed in discrimination of sweet taste elicited by sucrose. Stimulus specificity of taste sensitivity has generally not been found at the threshold level. However, Kaneda et al. (2000) observed no difference at detection threshold for sucrose between young and elderly subjects. Still, other researchers have concluded that age reduces sensitivity to sweetness as much as to other tastes (Bartoshuk et al., 1986; Bartoshuk, 1989; Stevens et al., 1995). Mojet et al. (2001) stated that the age effects found for sensitivity to any taste at the threshold level could be attributed predominantly to a generic taste loss.

2.2.3 Chemesthesis

The effect of aging on chemesthesis, i.e. trigeminal perception, has been much less studied than age effects on smell and taste perception. However, the few studies on the subject have resulted in the conclusion that aging weakens nasal trigeminal sensitivity, although not as strongly as it does olfaction (Murphy, 1983; Stevens and Cain 1986b; Laska, 2001). Furthermore, Laska (2001) found that while nasal trigeminal system undergoes impairment during aging it still contributes considerably to the quality discrimination of chemosensory stimuli.

Trigeminal and olfactory systems interact at multiple levels, and the interaction is an important determinant of odor sensations (Hummel and Livermore, 2002). According to Hummel et al. (1996), the age-related loss of olfactory function also leads to a decrease in trigeminal sensitivity. Wysocki et al. (2003) found that sensitivity in both nasal chemosensory functions (olfaction and chemesthesis) declined with advancing age, especially in individuals aged over 60 years. Ship (1999) suggested that a reduction of retronasal trigeminal sensitivity with age may result from causes similar to those for reduced olfactory capability.

2.3 Flavor perception of the elderly

2.3.1 Flavor perception process

Flavor of foods is a combination of the following three factors: 1) an olfactory stimulus, perceived by the olfactory receptors, which reaches the olfactory epithelium through the nasopharyngeal passage, 2) tastes that are soluble compounds eliciting sweet, salty, sour, bitter, and umami sensations primarily on the tongue, but also overall in the oral cavity, and 3) somatosensory factors, such as trigeminal sensations (astringency, pungency, cooling, etc.), texture and temperature which are perceived in both the oral and nasal cavities (Taylor and Linforth, 1996). Sensory properties can be different when smelled than when “eaten” for several reasons, including different temperature and humidity in the mouth and the air, saliva composition, chewing efficiency, different texture, mouthfeel, and food composition. These factors can result in different release of volatiles, thus affecting flavor perception (Taylor, 1996; Taylor and Linforth, 1996; Laing and Jinks, 1996).

Flavor perception arises from the central integration of the peripherally distinct sensory inputs (taste, smell, texture, temperature, sight, and even sound of foods) (Bartoshuk and Beauchamp, 1994). Gerber et al. (2003) found preliminary evidence for differential engagement of chemosensory regions with ortho- than with retronasal olfactory stimulation. There is also evidence that orthonasal and retronasal olfaction may interact differently with gustatory processing. Slotnick et al. (1997) showed that odors can potentiate a taste aversion but only when they are presented retronasally. According to Small et al. (2004), this may indicate a greater ability of the retronasal odors to influence the gustatory and flavor neural code.

Small et al. (2004) found that taste-smell integrations within a neural network underlying flavor perception were dependent on previous experience of taste/smell combinations and the mode of olfactory delivery (ortho/retro). This finding was in accord with Rozin’s proposal that olfaction may be seen as two functionally distinct senses: one sense for identifying objects at a distance (orthonasal perception) and another sense that contributes to flavor perception, and hence food identification, in the mouth (retronasal perception) (Rozin, 1982).

Prescott (1999) suggests that although the physiologic difference between these two perceptions may be only in the efficiency of the odor delivery to the olfactory epithelium the information delivered by each perception may differ in its cognitive impact. Small et al. (1997) concluded that flavor is not represented by a simple convergence of its component sensory modalities, but rather it is processed as a unique sensory experience. Flavor perception is thus a complex process of interactions between perceptual phenomena that occur when multiple sense organs and sensations are involved.

2.3.2 Effect of aging on flavor perception

Flavor perception changes with age. The change is mostly due to a deterioration in chemosensory acuity (Stevens and Cain, 1993). Flavor perception of the elderly is also affected by several other factors such as denture wearing, oral diseases, decreased salivary flow, and diminished muscular strength, leading to poorer chewing efficiency (Ship, 1999; Duffy et al., 1999).

Stevens and Cain (1993) have shown that older persons can suffer from impaired flavor discrimination for normal foods, which may reflect deficits in the sense of taste as well as in the sense of smell. According to Zanstra and de Graaf (1998), older subjects perceived high concentrations of citric acid as less sour than did younger age groups. Chauhan and Hawrysh (1988), by contrast, found no difference in psychophysical functions for citric acid in young and very old subjects. Schiffman (1997) suggests that older people's impaired olfactory function at a suprathreshold level leads to a bland flavor experience, which has been proposed to decrease the hedonic value of food. Moreover, Schiffman and Graham (2000) suggest that the elderly, as compared with the young, perceive tastes as being less intense, blunting their flavor experiences.

De Graaf et al. (1996) found that elderly subjects needed higher flavor ingredient concentrations than the young to obtain a similar perceived intensity level in foods and beverages. Furthermore, de Graaf et al. (1994) proposed that the age-related changes in perceptions of food flavors may depend on the specific flavor stimuli. Mattes (2002) suggested that the specificity and magnitude of chemosensory changes may not be uniform

across the sensory spectrum, i.e. the age-related weakening at a threshold level does not automatically lead to impaired perception of stimulus concentrations at a suprathreshold level (e.g. for taste: Bartoshuk et al., 1986). Furthermore, Mattes (2002) raised the question whether age-related changes at threshold level are significant at all for flavor perception if the perception at suprathreshold level remains virtually intact with age. However, Cain et al. (1990) proposed that elevated threshold levels do indeed affect the flavor perception of the elderly, as some of the flavor components fall under the detection threshold, resulting in an altered overall flavor experience.

One must still keep in mind that the age effect on flavor perception is not necessarily always negative. Of course, poor flavor perception may have the disadvantage of making older individuals oblivious to the presence of desired ingredients in foods, thus leading to a bland rather than to a rich experience. However, the disability to perceive all shades of flavor in food may also be beneficial by suppressing undesired flavor characteristics in certain foods (Cain et al., 1990). Wysocki and Pelchat (1993) found that the elderly with poor olfaction did not notice the aversive aspects of some food odors, and thus, did not respond negatively to them.

Although odor is proposed to be the major component of flavor of foods (Wysocki and Pelchat, 1993), the loss of olfactory function may lead to a greater contribution by taste perception to the overall flavor intensity (de Graaf et al., 1994) and quality (Duffy et al., 1995). This inevitably implies that the quality-specific nature of the changes in a taste system (e.g. Murphy and Gilmore, 1989) may alter the perception of food flavor, possibly also resulting in an unbalanced flavor experience. Duffy et al. (1995) suggested that loss of olfactory food flavor among the elderly could be compensated for by stronger taste qualities and appropriate texture, providing a pleasant non-olfactory variation in food.

The role of chemesthesis in the total picture of food flavor perception remains rather unclear. Murphy and Cain (1980) have suggested that the trigeminal system acts as a rallying point between anatomically and physiologically distinct olfactory and taste systems, resulting in an integrated perceptual system during eating. Philipsen et al. (1995) found that the elderly may also use visual cues in flavor perception; the overall flavor intensity of the elderly increased

with increasing color intensity, while no such effect was found in younger subjects. Compared with the young, the world of flavor sensations is likely to be quite different for the elderly.

2.4 Food acceptance and preferences of the elderly

2.4.1 Flavor acceptance and preferences

Olfaction contributes to food acceptance by mediating the perception of food odors and flavors (Schiffman and Warwick, 1993; Duffy et al., 1995). Age-associated loss in smell and taste acuity is proposed to lead to altered flavor perception and decreased acceptance of food among the elderly (Murphy, 1993; Schiffman and Warwick, 1993). As a consequence, elderly people may compensate for the altered flavor by making different food choices (Duffy et al., 1995; Rolls, 1999). Tuorila et al. (2001) found that by adding an appropriate aroma the hedonic quality of food could be improved somewhat among the elderly. Duffy et al. (1995) observed that the elderly with poor flavor perception reported a lower preference for some fruits and vegetables, pungent foods, and whole-grain breads and cereals. Olfactory dysfunction seemed to result in a lesser preference for foods with sour or bitter tastes.

According to Murphy and Gilmore (1989), the quality-specific changes in a taste system during aging may also have significant implications for food acceptability. Murphy (1993) reported that the age effects on preference do not appear to be related to generally lower perceived intensity. Instead, the overall flavor complex may be differentially perceived by the elderly and the young. Thus, when some of the components fall below an older person's threshold, the altered flavor may then drive the preference. Wysocki and Pelchat (1993) showed that perceived pleasantness and intensity of food-related odor contributed to elderly individuals' acceptance and willingness to eat something with a similar smell. In addition, Pelchat (2000) found that elderly people with reduced olfactory capacity were more willing to taste novel food than were the young with normal olfactory function.

Several authors have investigated, whether an association between chemosensory sensitivity and the preferred concentration of a flavor ingredient exists in different age groups. Murphy

and Withee (1986) showed that the elderly preferred higher concentrations of NaCl in low-sodium vegetable juices. Drewnowski et al. (1996), by contrast, described no overall difference in optimal salt concentrations between the elderly and young, but the elderly did prefer a lower salt concentration in chicken soups. Chauhan and Hawrysh (1988) reported that the citric acid level perceived as equally sour by both age groups was rated as more pleasant by the elderly than by the young, suggesting that the elderly subjects tolerate higher citric acid concentration in their hedonic responses. They proposed that the age differences in chemosensory preferences can be attributed to nonsensory factors (Chauhan and Hawrysh, 1988). Zandstra and de Graaf (1998) observed that the young, as compared with the elderly, had a lower preferred concentration of citric acid in an orange drink, while no clear difference between the age groups was found for orange flavor in the same product.

Mixed results have been described for food flavors; de Graaf et al. (1994) found the optimal flavor concentrations to be higher for the elderly than for younger subjects for bouillon, tomato juice, and orange flavor, whereas no difference was seen between the age groups for optimal concentrations of strawberry flavor and sucrose in yogurt. In another study, de Graaf et al. (1996) reported higher preferred concentrations of food flavor for the elderly in an orange lemonade, but no clear age differences for preferred flavor concentrations in bouillon, tomato soup, and chocolate custard.

Many studies have demonstrated that the elderly prefer higher sucrose concentrations than the young. Zandstra and de Graaf (1998) observed children and elderly subjects to be less sensitive to the sweetness of sucrose and to have higher optimal sucrose concentrations than young adults. De Jong et al. (1996) found that the elderly preferred higher sucrose concentrations than younger subjects in different breakfast items (orange lemonade, strawberry jam, and strawberry yogurt). In a study by Mojet et al. (in press), elderly men showed a higher preferred concentration for sweet tastants (sucrose and aspartame) than did the young. In addition, Kozłowska et al. (2003) reported that juice samples with the highest sucrose concentration received higher pleasantness scores from the elderly than from the young people. In a trial examining the relative importance of aroma, taste, and texture, the elderly preferred a high and the young a low sucrose concentration in a yogurt-type snack (Kälviäinen et al., 2003). Unquestionably, all of these studies show that these two age groups

have different preferences. However, Murphy (1993) has proposed that altered taste preferences may derive from sensory as well as from cognitive processes. In addition, the cohort effect plays a role in the observed differences in the flavor preferences of both groups.

2.4.2 Texture acceptance and preferences

Texture has sometimes been shown to be a more important driver of elderly people's food preferences than flavor. Compared with younger subjects, the elderly pay more attention to the texture of food (Forde and Delahunty, 2004) and are more demanding in this regard. The diminished ability to chew food because of dental deficiencies or full dentures can make some foods difficult to eat and may also weaken perceived flavor, resulting in changes in food preferences (Ship, 1999; Duffy et al., 1999). Elderly subjects with dental deficiencies, as compared with the fully dentate, have been found to like easier textures more (Roininen et al., 2003). Roininen et al. (2003) found that both the elderly and young adults considered carrot samples as difficult to eat if they needed a long chewing time. In addition, the young adults liked more difficult textures (e.g. rough, crispy, crunchy, hard) than did the elderly, but the easiest textures (e.g. boiled and pureed carrot samples) were not liked by either age group. Kälviäinen (2002), in turn, has demonstrated the elderly to appreciate easy eating experience.

Peleg (1993) suggested that it is possible to develop special foods for the elderly by increasing fragility and maintaining crunchiness or by making chewy foods that require a reduced mastication effort to minimize fatigue. Duffy et al. (1995) concluded that poor flavor perception should be compensated with taste and texture to maintain food enjoyment. Some other possibilities have been tested as well. Chan and Kane-Martinelli (1997) examined the effect of color intensity on overall acceptance of one savory and one sweet food, but they found no effect of color on acceptance by either young or elderly subjects.

2.4.3 Role of adaptation and habitual consumption in food acceptance

Although the aforementioned studies have shown age-related changes in food flavor acceptance and preferences, contrary views also exist. Stevens (1989) pointed out that it is

difficult to document a loss of eating enjoyment in healthy elderly people despite their diminished olfactory capabilities. While the elderly certainly have reduced olfactory capabilities, the effect of this impairment on food acceptance is less certain. Wysocki and Pelchat (1993) found that elderly people are often unaware of their impaired ability to smell and report no decrease in their appreciation of foods. Landis et al. (2003) suggested that subjective ratings of olfactory function are unreliable in healthy, untrained subjects mainly due to the limited attention the sense of smell receives in daily life.

Schiffman (1993) speculated that older individuals whose hedonic responses towards foods have been reduced due to loss of olfaction, may suffer concomitant losses in texture and taste sensitivities. Delahunty (2004), however, reported that losses in chemosensory function are not uniform across the senses. Therefore, although an elderly person may have lost ability in one sensory modality, another modality will likely still work normally, allowing continued discrimination between different foods. Forde and Delahunty (2004) suggested that the emphasis each individual places on the contribution of different sensory characteristics of a food to its overall quality can vary from one older person to another depending on the nature of their sensory impairment.

People's food preferences rely strongly on earlier food experiences and eating habits (Birch, 1999). The influence of earlier food experiences is likely to be even more pronounced in the elderly because their food history goes back over a longer period. Issanchou (2004) has suggested that the earlier eating habits are a more important driver in elderly people's food preferences than are those changes in chemosensory function that alter flavor perception. Moreover, Forde and Delahunty (2004) found that despite loss in sensory ability, the older group liked the same juices as the younger group, emphasizing that sensory deficit does not necessarily influence liking. Determining whether food preferences change with age based on the available data is impossible as all data are from cross-sectional studies. Only studies of the same persons over time can reduce the cohort effect, enabling true age-related changes in food acceptance and preferences to be detected.

2.5 Food intakes of the elderly

People's food intake changes over the course of aging. The daily volume of consumed foods and beverages (grams/day) declines as a function of age (Morley and Silver, 1988; Morley, 2001; Drewnowski and Shultz, 2001). The decreased food intakes may lead to deficiencies in energy and nutrients, and eventually, to malnutrition. The most extreme state of decreased food intake is called anorexia of aging (Morley and Silver, 1988; Horwitz et al., 2002). However, decreased food intake with age is a natural and even necessary phenomenon, as metabolism and physical activity decline. Decreased food intake is often associated with poor health status of the elderly (Rolls, 1993; Schiffman and Warwick, 1991; Schiffman, 1994). The frail elderly are at the greatest risk for the devastating consequences of malnutrition. The attendant morbidity and mortality associated with impaired nutritional status, particularly among institutionalized older adults, have been highlighted in several studies (Morley and Silver, 1988).

2.5.1 Reasons behind decreased food intakes

The reasons for decreased food intakes in old age are multiple. Many physiologic changes associated with age force people to adjust their food intakes downwards (Drewnowski and Shultz, 2001). Appetite often decreases with age and as a result, food intakes decrease as well (Hetherington, 1998). Moreover, age-associated changes in metabolism or physiological function may be partly responsible for the observed decline in energy intakes as well as for shifts in dietary choices and eating habits (Morley, 2001).

However, not all age-associated changes are caused by age alone. Health and functioning of the elderly are influenced by many factors other than biological senescence. The age-associated decline in function has been suggested to be caused by cumulative exposure to risk factors rather than aging per se (Drewnowski and Evans, 2001). A critical risk factor of malnutrition among the elderly is the declining need for energy due to a reduction in the amount of lean body mass and a more inactive lifestyle. While energy requirements decline,

many age-related physiologic changes increase the need for several nutrients (Blumberg, 1997).

Aging is associated with changes in the systems that regulate eating and drinking (Rolls, 1992; 1993). Dysregulation of food intake could put the elderly at high risk for nutritional disorders (Rolls, 1999). However, Rolls (1999) suggests that changes in the mechanism regulating energy intake may affect energy balance, with adjustments not necessarily being made for caloric deficits or surfeits. Additionally, aging involves increased activity of satiety factors, such as an increase in the levels of satiety hormone cholecystokinin (CCK), which makes elderly people to feel satiated at a rather early phase of eating (Morley and Silver, 1988).

The presence of variety in food choices tends to lead to greater food consumption (Rolls et al., 1981). Elderly people have, however, been found to be less responsive to variety than young people (Rolls, 1992; 1999). Sensory-specific satiety diminishing with age (Rolls and McDermott, 1991) is likely one reason for the lack of responsiveness to variety. Elderly people are therefore at higher risk of consuming a monotonous diet (Rolls and McDermott, 1991; Pelchat and Schaefer, 2000). The effect of restricted food choices on health and nutritional status can be serious; consumption of a varied diet is considered the most effective way of ensuring adequate intake of nutrients (Blumberg, 1997; Rolls, 1999).

Age-related deficits in smell and taste are commonly suggested to suppress appetite and food intake, causing nutritional problems in the elderly (Schiffman and Warwick, 1991; Rolls, 1999). However, little evidence has emerged relating diminished chemosensory functioning directly to low food intake and nutritional diseases (Rolls, 1999). In a recent study, poor smell perception of the elderly was associated with poor appetite and less hunger feelings, but the olfactory status was unrelated to energy intake and body mass index (de Jong et al., 1999). In another study, prominent smelling deficits in older women were found to change nutrient intake profile slightly, but the impact on nutrition and health was negligible (Duffy et al., 1995). Patients with chemosensory disorders are not inevitably at high risk for nutritional deficiencies (Mattes and Cowart, 1994).

Aging is accompanied by a variety of economic, psychological, and social changes that can compromise nutritional status (Darnton-Hill, 1992; Blumberg, 1997). A lack of help with food shopping and preparation, as well as poverty, may lead to decreased food intake (Morley and Silver, 1988; Hughes et al., 2004). Moreover, widowhood and bereavement often have a negative influence on appetite and food intake (Hetherington, 1998). Eating in social groups has been shown to enhance food intakes; healthy older adults respond to social contexts the same way as the young, by eating more (McAlpine et al., 2003). However, the opportunities to eat meals with family and friends may be fewer in old age (Hughes et al., 2004). Of the psychological factors, depression has been suggested to be a major cause of decreased appetite and food intake in the elderly (Morley and Silver, 1988). Paquet et al. (2003) found that everyday moods and emotions experienced at nonclinical levels may directly influence elderly persons' food intakes. The effect can also be indirect, occurring through perceived lower sensory quality of food (Paquet et al., 2003).

2.6 Psychophysical measurement of olfactory performance

Olfactory function may become impaired for a variety of reasons, including aging (e.g. Schiffman, 1997; Murphy et al., 2002), nasal polyposis and chronic rhinitis (Vento et al., 2001), head trauma (Temmel et al., 2002), medication (Schiffman, 1994), and certain disease states such as Parkinson's and Alzheimer's (Meshulam et al., 1998; Murphy, 1999). Indeed, olfactory loss can be the first clinical sign of a neurodegenerative disease (Doty, 2001). As olfaction provides humans with information on the surrounding chemical environment that allows us to detect such things as spoilage, smoke in the case of fire, and gas leaks, loss of the function will have a debilitating impact on our safety, health, and quality of life (Reiter and Costanzo, 2003).

Accurate testing devices are essential for detecting olfactory loss early, and to establish the validity, nature, and magnitude of the dysfunction. In recent decades, several psychophysical olfactory tests have been developed for clinical purposes to measure individual olfactory performance. The proliferation of handy olfactory tests has markedly increased the understanding of functional influences such as age, gender, and various disease states, on the

sense of smell in humans, (Doty, 2001). Table 1 presents eight widely employed olfactory tests and describes their specific purposes as well as their advantages and disadvantages.

Olfactory tests include various tasks such as odor detection threshold, memory, detection, discrimination, and identification on a suprathreshold level. Based on performance on a validated olfactory test, subjects receive a score that classifies them as normosmic, hyposmic, or anosmic. The cut-off scores for different olfactory diagnoses are determined in thorough testing of olfactory performance of individuals in different age groups. The testing aims at providing normative values for different age groups that can then be used as references against which the performance of subjects tested is compared (Doty et al. 1996; Kobal et al., 2000). If test performance suggests an olfactory dysfunction, the diagnosis can be confirmed by measuring olfactory event-related potentials to detect possible malingers (Kobal, 2003).

Odor identification is the most common task in commercialized tests because it is quick and easy to administer in clinical situation (Doty, 2001). The use of odor identification is based on the assumption that a person who perceives suprathreshold odors as weaker will find the odors more difficult to identify, and as a result, will identify fewer odors (Doty et al., 1984; Nordin et al., 1998; Cain et al., 1998). Murphy et al. (1991) claim that elevated odor detection thresholds and decreases in suprathreshold intensity perception merely reflect sensory dysfunction. Odor identification and recognition, in turn, are cognitively demanding tasks, and thus, the outcome may be affected by factors other than olfactory function per se (Cain et al., 1998; Larsson et al., 2000). According to Murphy et al. (1991), the age-related diminishment of odor identification derives partly from sensory changes and partly from cognitive changes. The cognitive contribution to the performance is naturally dependent on the demands of the task; free odor naming is a much more demanding task than cued naming, the former resulting in larger differences between the elderly and young (de Wijk and Cain, 1994).

Doty et al. (1994) conducted a large comparison between different olfactory tests, including odor detection, discrimination, identification, and recognition memory. They found that nominally distinct tests measured a common source of variance regardless of the task. They concluded that the tests cover different aspects of olfaction, together measuring overall

Table 1. Psychophysical tests for measuring olfactory performance.

Test*	Description of tasks	Advantages	Disadvantages
Amoore's Test ¹	Threshold for pyridine from odorless squeeze bottles	Rapid	Gives a limited picture of olfactory performance, as measures only threshold
University of Pennsylvania Smell Identification Test (UPSIT) ²	Identification of 40 scratch and sniff odors (microencapsulated) with aid of four alternatives/odor	Rapid; clearly differentiates anosmics, hyposmics, and normosmics	Odors are not cross-cultural; familiarity plays a role in performance; identification task demands cognitive function as well
Cross-Cultural Smell Identification Test (CC-SIT) ³	Developed from the UPSIT: Identification of 12 odors with aid of four alternatives/odor	Rapid; performance not dependent on culture, as odors chosen are cross-cultural	Compared with UPSIT, less sensitive in detecting subtle alterations in smell function; identification task demand cognitive function as well
Sniffin' Sticks ⁴	Threshold for n-butanol; discrimination of 16 odors; identification of 16 odors with aid of four alternatives/odor	Gives a versatile picture of olfaction, as three dimensions of olfaction are measured; clearly differentiates anosmics, hyposmics, and normosmics	Slow
Scandinavian Odor Identification Test (SOIT) ^{5,6}	Identification of 16 odors (presented in opaque glass vials) with aid of four alternatives/odor	Rapid; no cultural effects on odor identification between Finns and Swedes; sensitive to age-related changes in odor identification	Identification task demands cognitive function as well; possible cohort effect and ceiling effect
European Test of Olfactory Capabilities (ETOC) ⁷	Detection of 16 odors (16 series of four vials, of which one contains an odor stimulus, three are blank); identification of 16 odors with aid of four alternatives/odor	Rapid; culturally validated across European countries; sensitive to age-related changes in odor detection and identification	Identification task demands cognitive function as well; possible cohort effect and ceiling effect
Alcohol Sniff Test (AST) ⁸	A standard 70% isopropyl alcohol preparation pad, placed beneath subject's nose, who indicates when the odor is detected. Active sniffing and deep inspiration are discouraged.	Rapid test that can be used to screen olfactory function	Gives a limited picture of olfactory performance
Sniff Magnitude Test ^{9,10}	Three odors in an odor presentation device that is positioned under both external nostrils and does not impede normal respiration. The device measures sniffing behavior.	No cognitive demand on the subject; suitable for testing of children, the neurologically impaired, and the elderly, correlates well with other tests	Responses to unpleasant odors are more intense than to pleasant odors

*References: ¹Amoore and Ollman, 1983; ²Doty et al., 1984; ³Doty et al., 1996; ⁴Hummel et al., 1997; ⁵Nordin et al., 1998; ⁶Nordin et al., 2002; ⁷Thomas-Danguin et al., 2003; ⁸Davidson and Murphy, 1997; ^{9,10}Frank et al., 2003

olfactory performance. Doty et al. (1995) proposed test reliability to depend more on test length than on the nature of the stimuli (single or multiple component) included. Doty and Laing (2003) suggested that sampling more elements of the olfactory system by using multicomponent stimuli would result in a more sensitive test.

2.7 Flavor enhancement as a tool for increasing the hedonic value of foods

Flavor enhancement as a tool is based on adding simulated flavor ingredients or aromas to enhance the flavor of foods; for example, one can add carrot odor to amplify the flavor of fresh carrots, and bacon odor can be added to soups and vegetables, etc. (Schiffman and Warwick, 1989). More intense flavor of food is proposed to compensate for age-related perceptual losses, improving food palatability and acceptance and resulting in increased food intakes (Schiffman and Warwick, 1988; 1989).

2.7.1 Applications of flavor enhancement

The effectiveness of flavor enhancement has been tested by only a few researchers, and the outcomes of the studies are summarized in Table 2. As can be seen, some researchers have demonstrated benefits of flavor enhancement. Yet, evidence of a benefit is not particularly strong, and some contradictory results have also been found. An increase of hedonic value of foods among the elderly is the most common advantage cited for flavor-enhanced food (Schiffman and Warwick, 1988; Griep et al., 1997; Schiffman, 1998; Elsner et al., 1998). Although Griep et al. (2000) found that the elderly preferred flavor-enhanced, preference for a particular food did not result in increased intake. Schiffman and Warwick (1993) managed to show an increase of food intakes in the elderly eating flavor-enhanced meals. However, the increase was significant for only 3 of 20 foods. Still, the increased intakes resulting from the flavor enhancement were demonstrated to improve immune status, grip strength, and well-being (Schiffman and Warwick, 1993). Mathey et al. (2001) found an increase in the intake of cooked meals, but no increase in daily dietary intakes. Interestingly, the elderly subjects in the group consuming flavor-enhanced meals gained weight during the intervention, despite a slight decrease in energy intakes. Mattes (2002) in commenting on this contradictory result raised a question about the veracity of the dietary records. Flavor

Table 2. Flavor enhancement as a tool for improving hedonic value of food and increasing food intakes in the elderly.

Description of procedure	Food acceptance	Food intakes	Nutrient/energy intakes	Reference
Elderly from a retirement home n=39 (4 M, 35 F; mean age 84.6 y) Two 3-week periods: one with unenhanced foods, another with flavor-enhanced foods (roast, beef, ham, natural bacon, prime beef, maple syrup and cheese), at each meal 1-2 foods (soups, gravies, eggs, vegetables, grits, stews, sauces, oatmeal, macaroni) enhanced	Not measured	Increased, but significant only for 3 of 20 foods The flavors stimulating intakes were roast beef, ham, and bacon	No effect, but slight decreases in fat and sodium intakes in the enhanced condition Improved immune status and grip strength	Schiffman and Warwick, 1993
Elderly from a retirement center n=50 (mean age 81.7 y) Two 4-week periods: one with unenhanced food, another with MSG/flavor-enhanced foods, at each meal 1-3 foods (meats, soups, gravies, eggs, vegetables, grits, stews, sauces, macaroni) enhanced	Overall liking increased due to both MSG and flavors Order of improvement: soups>meats>gravies>sauces>stews	Increased, but not specified for which foods	No effect	Schiffman, 1998
Elderly from the geriatric unit of a hospital n=20, 9 M (75 y), 11 F (79 y) + young adults Two days, meals with either low or high flavor levels in random order: meat substitute with chicken flavor+marjoram, yogurt with cherry flavor, and soup, flavor not specified	Many of the elderly had no preference for either flavor level, but those who had, preferred the high flavor levels of each food	The elderly ate more soup than the young, irrespective of the flavor level	Not measured	Griep et al., 1997
Free-living elderly + young adults n=260 (64 M, 196 F; 19-98 y) for yogurt testing (strawberry flavor) n=120 (48 M, 72 F; 20-90 y) for meat substitute testing (chicken flavor+marjoram) Tasting session+400 g yogurt for ad libitum consumption (either high or low flavor)	For both yogurt and meat substitute, the relative number preferring the high flavor level increased significantly with age	Relative consumption of high flavor yogurt was not correlated with age	No effect	Griep et al., 2000
Elderly from nursing home n(control)=31 (83 y); n(flavor)=36 (84.6 y) Group-intervention design, 17 weeks (1+16) Cooked meals enhanced with flavors of chicken, beef bouillon, turkey, and lemon butter	Not measured, but daily feeling of hunger increased in the 'flavor group'		Daily energy intake decreased (absolute change), but surprisingly, the 'flavor group' gained weight during the test period	Mathey et al., 2001

M=male; F=female

enhancement has been suggested to improve the quality of life via increased enjoyment of food (Schiffman and Graham, 2000). Mattes and Cowart (1994), concluded that while increasing the appeal of foods by adding flavor may enhance the quality of life of people suffering from chemosensory loss it would probably have little nutritional relevance.

Contradictory results of the effectiveness of flavor enhancement have also been shown. More intense food flavor has been found to have little effect or even a deteriorious impact on older individuals' liking of a particular food (Raeker et al., 2003). Thus, the role of chemosensory changes in food acceptance and compensation for these changes by intensifying food flavor warrant further investigation. In studies in which the chemosensory function has been measured, the connection between impaired chemosensory capabilities and liking of intensified food flavor has been either weak or totally absent (Michon and Delahunty, 2003; Rousseau et al., 2003; Gourillon et al., 2003). Based on the findings of large-scale flavor enhancement studies conducted in different European countries, Issanchou (2004) concluded that flavor enhancement has a limited effect on increasing food liking in the elderly population.

2.7.2 Limitations of flavor enhancement

Although flavor enhancement has in a few cases been shown to be a useful tool for increasing food palatability among the elderly, it has not increased food intakes. Furthermore, even the increase in the palatability of food has been inconsistent. In addition, flavor enhancement may decrease food palatability in subjects with normal chemosensory function, leading to reduced energy intakes (Schiffman and Warwick, 1988). The benefit of enhanced flavor is also questionable since the progressive diminishment of smell and taste perception with aging often goes unnoticed by individual (Stevens et al., 1984; Wysocki and Pelchat, 1993). Moreover, Mattes (2002) highlighted the difficulty in determining the optimal level and type of flavor, as age-related chemosensory deficits may be quality-specific and can vary largely in magnitude between individuals (de Graaf et al., 1996).

Totally anosmic individuals do not benefit from flavor enhancement, as they are unable to smell and perceive the olfactory component in flavor regardless of the intensity (Schiffman

and Warwick, 1988; Mattes, 2002). To be able to take these issues into account, it would be useful to have background knowledge of the chemosensory function of target subjects. However, methods of identifying individuals who might benefit from enhanced food aroma have not yet been devised. Murphy et al. (1989) have speculated about the existence of a sensory fitness property much like that of physical fitness; i.e. do persons with good sensory functioning also have good taste functioning, or is good sensory functioning associated with good cognitive functioning? Chemosensory performance tests may provide a helpful tool for determining sensory fitness. The performance should, however, be able to predict the perception of flavor in food systems, otherwise it would not be of much use. However, because the diminishment of chemosensory functioning appears gradually, it may mask awareness of such changes and lead to adaptation to the altered flavor of food, making flavor enhancement unnecessary (Rolls, 1992).

Researchers have speculated that the impaired function of one sensory modality (e.g. olfaction) may be compensated by another sensory modality (e.g. gustation) by enhancing food intensity, thereby contributing to overall flavor (Duffy et al., 1995). For example, de Jong et al. (1996) found that elderly people prefer higher sweetness intensity in food, suggesting that sweetness may compensate for a lower olfactory functioning. However, these authors did not observe any increase in the amount of food eaten as a result of enhanced sweetness. According to Duffy et al. (1995), the importance of the taste of food may increase among those elderly whose olfactory capacity is limited. The quality-specific weakening of the sense of taste, however, also makes this aspect quite complicated.

2.8 Aims of the study

The general aim of this thesis was to examine the role of chemical senses, especially olfaction, on flavor perception and food acceptance of the elderly.

Detailed aims were as follows:

- * to examine the effectiveness of flavor enhancement in improving food acceptance of the elderly
- * to examine the ability of olfactory tests to predict subject's food odor and flavor perception

3 MATERIALS AND METHODS

3.1 General description of the studies

This thesis consists of six sensory experiments, reported in five papers (I-V). Study I evaluated the effects of chemosensory performance of the young and the elderly on pleasantness and optimal intensity ratings of odor, flavor, and oral cooling in flavored yogurts. Study II examined the effects of heightened aroma concentration on the pleasantness and intake of a snack product in elderly and young consumers over repeated exposures. An oat bran product flavored with regular and high aroma concentrations, was tested in two tasting sessions and in a six-day home-use by the elderly and young. The subjects rated the odor and flavor intensity and pleasantness and performed an olfactory test. The olfactory performance was set against the hedonic responses and intakes of the flavor-enhanced product to determine any relationship between them. Study III concentrated on methodological aspects of olfactory performance, investigating the correspondence between three olfactory tests and their ability to predict ortho- and retronasal intensity ratings of simple aqueous solutions in anosmic, hyposmic, and normosmic subjects. Study IV continued with the same theme, examining the predictive ability of odor detection and identification performance on ortho- and retronasal intensity ratings of simple aqueous solutions among young and elderly subjects. The study was extended to examine the predictive ability of olfactory performance on intensity ratings for complex beverages and a semi-solid food (Experiments 1 and 2). Study V examined alternative means of boosting food intakes of elderly individuals varying in olfactory and mood status in two experimental conditions: 1) flavor of smoked hams was enhanced with pepper mix or smoke aroma and 2) a variety of cold cuts was provided. The intake measurements in this study were defined as an indicator of acceptance. The aims, subjects, food samples, modifications, measures rated, and chemosensory tests used in Studies I-V are described in Table 3. Only a general description of the experimental procedures is given in this section. For more detailed information, see Studies I-V in the appendix.

Table 3. Aims, subjects, samples, measures rated, and chemosensory tests used in Studies I-V.

Aim	Subjects	Samples, modifications, and ratings	Chemosensory and other tests
I To examine the interactions between different sensory modalities and the effect of trigeminal stimuli on perception and pleasantness	<u>Young adults</u> n=47 (11 M, 36 F), 20-35 y <u>Elderly</u> n=45 (4 M, 41 F), 65-82 y <u>Trained sensory panel</u> n=10 (3 M, 7 F), 25-40 y	<u>Samples:</u> Natural yogurt with added odor, taste, and trigeminal stimulus: Lemon aroma: 0.2% or 0.8% Sucrose: 6% or 10% Menthol: 0.004% or 0.012% <u>Ratings:</u> optimal odor, flavor, and cooling intensity, pleasantness	Odor detection and identification (ETOC) ¹ Taste identification and intensity judgment ² Trigeminal stimuli discrimination (menthol and piperine) ³
II To examine the effects of heightened aroma concentration on pleasantness and intake of a snack product over repeated exposures	<u>Young adults</u> n=58 (3 M, 55 F), 18-34 y <u>Elderly</u> n=50 (12 M, 38 F), 63-85 y <u>Trained sensory panel</u> n=9 (2 M 7 F), 25-41 y	<u>Samples:</u> Red berry-flavored fermented oat bran product with added aroma: Currant aroma: 0.02% or 0.78% <u>Ratings:</u> odor and flavor intensity, pleasantness, intakes	Odor detection and identification (ETOC) ¹
III To examine the capability of three olfactory tests to similarly classify subjects as anosmics, hyposmics, or normosmics, and the relationship between test performance and suprathreshold ortho- and retronasal odor intensity ratings	<u>Anosmics</u> n=11 (6 M 5 F), 15-72 y <u>Hyposmics</u> n=10 (3 M, 7 F), 25-84 y <u>Normosmics</u> n=27 (6 M, 21 F), 22-81 y	<u>Samples:</u> Aqueous solutions of aromas: Lemon: 0%, 0.08% or 0.17% Vanilla: 0%, 0.05% or 0.31% <u>Ratings:</u> odor and flavor intensity	Odor detection and identification (ETOC) ¹ Odor identification (CC-SIT) ⁴ Odor discrimination and identification, threshold for n-butanol (Sniffin' Sticks) ⁵
IV To examine the extent to which performance on an odor detection and identification test predicts individual ortho- and retronasal odor intensity ratings in aqueous solutions and in complex food systems	<u>Young adults</u> Exp1:n=32 (6 M, 26 F), 22-36 y Exp2:n=10 (3 M, 7 F), 22-29 y <u>Elderly</u> Exp1:n=27 (3 M 24 F), 66-83 y Exp2:n=17 (2 M, 15 F), 67-84 y	<u>Samples:</u> Aqueous solutions, whey drink, grape juice, natural yogurt with added aromas: Lemon: 0%, 0.08%, 0.17%, 0.36% Vanilla: 0%, 0.05%, 0.31%, 0.8% <u>Ratings:</u> odor and flavor intensity	Odor detection and identification (ETOC) ¹
V To examine whether olfactory function and mood status affect liking and intakes of cold cuts in two experimental conditions: when 1) flavor is enhanced or 2) variety is provided	<u>Elderly</u> n=60 (6 M, 54 F), 61-86 y	<u>Samples:</u> Experimental smoked hams with: smoke aroma: 0.07% or pepper mix: 0.46% Commercial smoked ham, cooked ham, pepper ham, bologna <u>Ratings/measures:</u> odor and flavor intensity, liking, intakes	Odor identification (SOIT) ⁶ Profile of Mood States (bi-polar) ⁷

M=male, F=female; References: ¹Thomas-Danguin et al., 2003; ²Johansson et al., submitted; ³Lähteenmäki et al., 2001 ⁴Doty et al., 1996; ⁵Hummel et al., 1997; ⁶Nordin et al., 1998; ⁷Lorr and McNair, 1988

3.2 Subjects

Subjects comprised young adults (18-36 years) and the elderly (>60 years, majority >65 years), and, in one study (III), anosmic subjects. Young adults were recruited from among the staff and students of the University of Helsinki, while elderly subjects were recruited from service centers and clubs for senior citizens in Helsinki. The anosmic subjects (III) were patients of the Ear, Nose and Throat (ENT) clinic of Helsinki University Central Hospital. In three studies (I, II, IV), a trained sensory panel was used in pre-tests and in creating sensory profiles for the samples. The subjects for the trained panels were staff and students from the University of Helsinki, and all had previous experience in sensory evaluation. See Table 3 for age and gender distributions.

3.3 Samples

Five types of food samples were used in the studies: natural yogurt (I, IV), berry-flavored fermented oat bran product, which is a snack-type semi-solid food similar to yogurt (II), apple-flavored whey drink (IV), grape juice (IV), and cold cuts (V). All food types were modified with regard to flavor. The flavor of natural yogurt was modified in a 2x2x2 factorial design for three sensory modalities with lemon aroma (odor), sucrose (taste), and menthol (trigeminal) in Study I, and with lemon aroma or vanilla aroma in Study IV. Similar modifications were conducted for the grape juice. The flavor of the fermented oat bran product was modified with currant aroma. The apple-flavored whey drinks were modified by adding vanilla aroma. The grape juice and natural yogurt (IV) were flavored with vanilla aroma or lemon aroma. The flavor of cold cuts (smoked hams) was modified with smoke aroma or pepper mix. In addition to these hams, Study V also included a variety of commercial cold cuts without flavor modifications. In Studies III and IV, aqueous solutions flavored with vanilla aroma or lemon aroma were also used. For more information on the modifications, see Table 3 and Studies I-V.

3.4 Procedure

In Study I, a trained panel was used in a pre-test to determine the concentrations of odor, taste, and trigeminal stimuli by a magnitude-matching method. Concentrations were selected to be equally intense in each of the three sensory modalities. The trained panel also created a sensory profile of the samples. Young and elderly subjects rated the samples for pleasantness using a hedonic scale, and for optimal intensity of odor, flavor, and oral cooling using a relative-to-ideal scale. The subjects performed tests that measured their olfactory, gustatory, and trigeminal capabilities, and filled in a background questionnaire. The olfactory test (ETOC, see Table 1) measured odor detection and identification abilities. The taste test consisted of 16 taste solutions with four concentrations of sweet, salty, sour, and bitter tastes to be identified and rated for intensity using labeled magnitude scale (LMS). The trigeminal test included ascending concentration series of solutions pairs with and without stimuli (piperine or menthol) to be discriminated. The evaluations and tests were conducted in the sensory laboratory at the University of Helsinki.

Study II consisted of two evaluation sessions and a six-day home-use period between sessions. Young and elderly subjects rated the two samples of fermented oat bran product for odor and flavor intensity as well as for pleasantness. The subjects also performed an olfactory test (Table 3) that measured their odor detection and identification abilities, and filled in a background questionnaire. In the evaluation sessions, the samples were presented side-by-side, while in home-use the samples were rated monadically. For home-use, the subjects received six packages (150 g each) of the sample, three packages at both flavor levels to be rated one sample per day. The intake was measured by asking the subjects to indicate the amount eaten in a booklet with a visual scale. The evaluation sessions for the young were conducted in the sensory laboratory at the University of Helsinki, and for the elderly in four senior citizen service centers in Helsinki.

In Study III, three olfactory tests were compared for their ability to yield a similar olfactory diagnosis (normal, hyposmia, or anosmia) for subjects on an individual level. The correspondence between performance in the three olfactory tests and the ratings for ortho- and retronasal odor intensity was also studied. The olfactory tests included four different

tasks: odor detection, identification, discrimination, and threshold measurement (Tables 1 and 3). All subjects completed the three olfactory tests, rated aqueous solutions of vanilla and lemon aroma for odor and flavor intensity, and filled in a background questionnaire. The tests and evaluations were conducted at three locations: in the sensory laboratory at the University of Helsinki, in downtown Helsinki at the Kamppi service center for senior citizens, and in the ENT clinic of Helsinki University Central Hospital.

Study IV comprised two experiments. In both experiments, the subjects performed an olfactory test (ETOC, see Table 1) and rated simple aqueous solutions, beverages, and one semi-solid food sample with added vanilla or lemon aroma for odor and flavor intensity. In the first experiment, only one medium and one aroma was tested, while in the second experiment three media and two aromas were tested. The evaluation sessions for the young were conducted in the sensory laboratory at the University of Helsinki, while the elderly performed the tasks at the Kamppi service center for senior citizens in Helsinki.

Study V consisted of two evaluation sessions and two successive six-day home-use periods between sessions. In the evaluation sessions, the elderly subjects rated the samples for odor and flavor intensity and for liking. For home-use, the subjects received a total of 600 g of the sample per period to be consumed ad libitum and were asked to rate the samples for liking. The intake was measured by weighing left-overs. Two experimental conditions were conducted in the study. Half of the subjects received samples with regular and enhanced flavor level for home-use, one type of flavor for the first period and another type for the second period. The other half of the subjects received a variety of samples for home-use, the variety being similar in both periods. The subjects also performed an olfactory test (SOIT, see Table 1) and filled in a background questionnaire. Their mood states were measured with a Profile of Mood States (POMS, bi-polar) scale. The evaluations and tests were conducted in the sensory laboratory at the University of Helsinki, in two senior citizen service centers, and in one senior club in Helsinki.

3.5 Data analysis

The data were analyzed applying standard statistical procedures (analysis of variance, Pearson's and Spearman's correlation coefficients, principal component analysis, and structural equation model), as described in the original papers (I-V). The statistical programs used in the analyses were SPSS for Windows and LISREL.

The following data were analyzed using analysis of variance: the effects of sample modifications on the sensory ratings of the trained panel as well as on the hedonic ratings of the young and elderly, the effect of age on performance in chemosensory tests, and the effects of age and chemosensory performance on hedonic ratings (Study I); the effects of aroma concentration on the sensory and hedonic ratings as well as on intakes of the young and elderly in tasting sessions and in home-use, the effects of age and health on olfactory performance, and the effects of age and olfactory performance on sensory and hedonic ratings and intakes (Study II); the performance of subjects with different olfactory diagnoses in three olfactory tests and in suprathreshold ortho- and retronasal odor intensity ratings (Study III); the effect of age group on odor detection and identification abilities and on suprathreshold ortho- and retronasal odor intensity ratings, and the predictive ability of olfactory performance on the ortho- and retronasal odor intensity ratings (Study IV); the effects of two conditions, flavor enhancement and provision of variety, on the intakes of cold cuts among the elderly, and the effect of sample as well as olfactory performance and mood states on the hedonic responses and intakes (Study V).

Spearman's correlation coefficient was used to test the correlations between test scores and intensity ratings (Study III). Pearson's correlation coefficient was used to test the correlations between the olfactory test scores and intensity ratings as well as between the scores and age in the elderly group (Study IV).

Principal component analysis (PCA) was used to examine the relations between the different olfactory tests and intensity ratings (Study III). Recursive path analysis models were conducted to test the putative causal relationships between variables associated with the intakes in two conditions (*Enhancement* and *Variety*) (Study V).

4 RESULTS

4.1 Chemosensory performance of the young and elderly

The young outperformed the elderly in odor detection (I-IV), odor identification (I-V), and odor discrimination (III). However, no difference between the age groups was found in threshold for n-butanol (III). More variation existed in the olfactory scores of the elderly than in those of the young (I: Fig. 2, II-V); thus, some of the elderly performed as well as most of the young. Health status of the elderly affected their olfactory performance. The poorer the health, the poorer the odor detection (II) and identification (V) capabilities. Anosmic patients performed significantly poorer than hyposmics and normosmics in all three tests used in Study III.

Gustatory function was measured with a taste test that consisted of identification and intensity judgment of taste solutions. Overall, the young performed better in the taste test (I). However, the performance was taste-specific; the young identified sour, bitter, and salty tastes better than the elderly, while the elderly were superior in identifying sweet taste (I: Fig. 3). In intensity judgments, the young rated sour, bitter, and salty tastes as more intense than the elderly, but the age groups did not differ from each other in the intensity ratings for sweet taste (I).

Sensitivity to trigeminal stimuli was measured with a discrimination test, which revealed that sensitivity was stimulus-specific. The young were more sensitive to oral cooling from menthol than the elderly (I: Fig. 4). The two age groups did not, however, differ from each other in perception of oral burning from piperine (I).

4.2 Effect of age group on odor and flavor perception

The young did not necessarily rate the orthonasal (odor) and retronasal (flavor) odors as more intense than the elderly (I-II, IV). Still, the young perceived a larger difference in the orthonasal odor intensities between different aroma concentrations (I, II, IV, V), while the

retronasal intensity ratings of the two age groups were closer to each other (I, II: Fig. 2, IV, V).

4.3 Effect of chemosensory performance on odor and flavor perception

Sensory responses of the elderly to flavored yogurts (I: Table 5, Fig. 5) were strongly affected by their chemosensory performance. Generally, poor chemosensory performance was related to more intense ideal flavor and oral coolness. However, with regard to sweet taste, good performance was related to more intense ideal flavor and oral coolness. Poor olfactory and trigeminal performance led to increased overall pleasantness ratings. Study IV showed that those elderly individuals whose olfactory performance was poor were unable to distinguish between different aroma concentrations. Their ratings of overall flavor intensity of whey drink decreased with increasing vanilla aroma concentration. Thus, poor chemosensory performance resulted in a somewhat biased flavor perception, which also affected hedonic responses.

A moderate link between olfactory performance and orthonasal odor intensity ratings for simple aqueous solutions and more complex beverages existed (III: Fig. 1d, IV: Figs 1, 2, 3a). A relationship was also present between olfactory performance and retronasal odor (flavor) intensity ratings for simple aqueous solutions (IV: Figs 1, 2, 3b). Hence, performance on odor detection and identification tasks predicted the suprathreshold ortho- and retronasal intensity ratings for simple solutions. However, practically no connection existed between olfactory performance and retronasal odor perception of complex beverages and a semi-solid food (IV: Fig. 3b). Thus, the predictive ability of olfactory performance on retronasal odor intensity ratings was not ecologically valid.

4.4 Hedonic responses towards flavor enhancement

The effects of flavor enhancement were investigated in Studies I, II, and V. In Study I, the flavor of yogurt samples was modified for three sensory modalities: odor, taste, and trigeminal. The pleasantness ratings of the young and elderly did not differ from each other. Overall, the trigeminal stimulus (menthol) dominated the hedonic responses, while odor

(lemon aroma) and taste (sucrose) stimuli did not significantly affect the hedonic responses (I).

In Study II, flavor enhancement by adding currant aroma to a snack-type fermented oat bran product decreased pleasantness ratings of both the elderly and the young. However, elderly subjects' pleasantness ratings for regular and enhanced samples were brought closer together, mostly due to the increasing popularity of the flavor-enhanced sample. Compared with the young, elderly subjects' hedonic responses were less affected by the flavor changes caused by aroma addition. Flavor enhancement did not increase the hedonic value of food among the elderly in general, nor did poor olfactory capabilities lead to liking for stronger flavors (II: Fig. 3a, V: Fig. 3b).

The liking of flavor enhancement was strongly dependent on the added stimulus (V: Fig. 2a). Responses to added flavor were also age-dependent; the youngest members of the elderly group rejected the strong flavor, while the liking ratings of the oldest in the group were virtually the same regardless of flavor level (V: Fig. 3a). Moreover, depressed mood generally decreased liking, especially for the food with enhanced flavor (V: Fig. 3c).

4.5 Effect of flavor enhancement on intake

Flavor enhancement did not increase elderly people's intakes of the food products used in Studies II and V. In fact, the elderly subjects ate less (II) or equal amounts (V: Fig. 4a) of the flavor-intensified products as compared with the regular products. Intakes were affected by subjects' health status; those with poor health ate smaller amounts than their healthier counterparts (II). Moreover, olfactory performance was related to overall intakes, but the effect was dependent on the food product. Those with poor olfactory performance had decreased intakes of fermented oat bran snack products (II: Fig. 4). By contrast, the overall intakes of cold cuts were higher in subjects with olfactory deficits (V: Fig. 5a). The effects of olfactory performance on intakes were not dependent on the flavor level (II, V). Energetic mood increased intakes, while tired subjects ate less (V).

4.6 Effect of variety on intakes

Variety did not increase overall intakes of elderly subjects (V). However, the subjects did eat significantly more cold cuts than they did regularly, according to their self-reported frequencies of use, but the increase was more due to the ad libitum condition than to variety. Those cold cuts that the subjects had previously consumed the most were also eaten the most during the study. Thus, familiarity was an important factor for increased intake.

5 DISCUSSION

5.1 Method

5.1.1 Subjects

The young subjects participating in this study were recruited from among the staff and students of the University of Helsinki. The use of University staff and students naturally narrows the possibility of generalizing the results, as these subjects most likely differ from the total population of Helsinki, not to mention other parts of Finland. The elderly subjects, in turn, were recruited from the service centers for the elderly. They were independently-living and subjectively healthy, did most of their grocery shopping by themselves, and made their own eating decisions. They all resided in the capital city area (Helsinki), thus possibly differing from the elderly living outside the capital city area. Dobalian et al., (2003) have found that residents in nursing homes of rural areas were less likely to be diagnosed with depression compared with those living in nursing homes in large metropolitan areas. Moreover, elderly respondents in rural areas reported a substantially 'healthier' diet than their urban peers (Morgan et al., 2000). Paul et al. (2003) found that elderly living in rural areas have more positive attitude towards aging than do the elderly living in urban areas.

The site of recruitment imposes certain limitations on the characteristics of elderly subjects. These subjects were rather healthy, optimistic and outgoing, the so-called 'successfully' aged, and thus, the potential for nutritional problems was lower than it would have been in sick, institutionalized individuals. Although variability in many functions was present in this group of elderly also, the other, 'unsuccessfully' aged pole was not represented here. It is difficult to reach independently living elderly representing the 'unsuccessfully' aged, as they most likely do not visit any service centers or senior clubs. Other strategies in recruitment should have been used, and even then, the 'unsuccessfully' aged possibly would not have wanted or have been incapable to participate in the studies. Thus, reaching those elderly subjects who suffer from food-related problems is extremely difficult, if one criterion is to only recruit independently-living elderly individuals. The 'unsuccessfully' aged subjects would need different approach and methods than those used in this study. Despite this

limitation, some clear trends in flavor perception, food acceptance, and intakes of the two age groups were covered with our subjects.

The results cannot be generalized to the Finnish population for another reason as well. The gender distribution was uneven, with women representing the majority of the subject population. This was likely the case for two reasons: 1) women were more willing to participate in the studies than men in both the young and the elderly age groups and 2) the majority of the elderly population visiting service centers and senior clubs consisted of women.

5.1.2 Variation within the group of elderly

Elderly people are a challenging group to study, as the variation in many types of functions is large. The diversity turns out to limit the possibility to generalize the results to total population of the elderly. The age of retirement is often used as the defining age of the elderly, and earlier studies of the aging population have frequently clustered all adults aged 65 years or over into the same group. Although age per se is not always the best descriptor of an individual's functions, recently retired older adults are likely to be more prosperous, active, and healthy than elderly persons in their 80s (Hetherington, 1998). For instance, the prevalence of chronic olfactory problems among the elderly increases with age, being more frequent at the age of 80 than at 60 (Murphy et al., 2002).

The high variation among the elderly group makes it difficult to apply flavor enhancement widely. One problem with flavor enhancement as a method, is determining the optimal dose of flavor ingredients to add. Given the gradual nature of the impairment of chemosensory function and the great variation in chemosensory capabilities, health, and other features in the elderly population, achieving a well-balanced, high-impact flavor is challenging (Mattes, 2002; Popper and Kroll, 2003). An increase in flavor intensity might be perceived as an enhancement by some of the elderly, but as too intense by others, depending on their chemosensory acuities (Popper and Kroll, 2003). Compound specific sensitivity of the subjects also limits the feasibility of flavor enhancement.

The impact of increased variety on the results was seen in Study V, where the ‘young-old’ (<75 years of age) and the ‘old-old’ (≥ 75 years of age) responded remarkably differently in their ratings of liking. The ‘old-old’ were unresponsive regardless of the flavor level in their hedonic ratings, while the ‘young-old’ expressed their preference in their ratings. Earlier studies (e.g. Tuorila et al., 1998; Pelchat and Schaefer, 2000) have suggested that elderly people tend to be more positive than the young in their hedonic responses. This is probably an outcome of a cohort effect that undoubtedly plays a role in cross-sectional studies. The response tendency may be due to the overall poorer discriminative ability of the elderly or simply to the willingness of the elderly to please the experimenter. The different responses of the ‘young-old’ and the ‘old-old’ may thus be explained by the tendency to give more positive hedonic responses increasing with age within the elderly group as well. Alternatively, the oldest individuals may have difficulties in transferring their feelings to a scale and also in expressing their dislike (Kozłowska et al., 2003). The difficulties may arise from the elderly being inexperienced in using any kind of scale. Study I did show that elderly people can express their dislike when a sample holds no appeal.

One issue that is related to the sensory responses of the elderly in particular is their tendency to give false positives. Thus, they report to perceive a stimulus in a medium where it is lacking. This was seen especially in Study IV. Murphy et al. (1991) have also discussed the high number of false-positive intensity ratings given to blanks by the elderly. The tendency to give false positives might be due to the perceptual uncertainty of the elderly. According to Stevens and Cain (1986a), such a response bias is practically inevitable when applying the same stimulus conditions to two groups with different chemosensory sensitivity.

Either way, generalization of the results of the sensory and hedonic responses of the elderly would lead to a situation that they are not true for either the ‘young-old’ or the ‘old-old’, nor for ‘good olfactory performers’ or ‘poor olfactory performers’. In further research, it would make more sense to divide the elderly into subgroups based on age, health, olfactory performance, or other suitable characteristics, rather than treating them as one homogeneous group, which they obviously do not represent.

5.1.3 Limitations of chemosensory tests and intake measurements

The subjects were tested for their chemosensory acuity using various instruments. Although the results from chemosensory testing were in line with the findings of other researchers, they should still be interpreted with caution. First, the taste test and the trigeminal test used in Study I were not validated methods. The concentrations of the stimuli in these tests were not thoroughly tested, but rather decided solely based on literature. Second, the elderly found it difficult to use the labeled magnitude scale (LMS, see Green et al., 1993) in the taste test to rate the intensity of taste stimuli, possibly influencing the results. Furthermore, the appropriateness of employing the LMS scale for these particular stimuli was questionable because of the rather narrow concentration range. Even the highest concentrations of taste stimuli could not be assumed to receive very high estimations of intensity.

When discussing observations of diminishing chemosensory capabilities, one should keep in mind that they derive exclusively from cross-sectional studies and thus have significant limitations. Only studies of the same persons over time can reduce the inevitable confounders resulting from comparisons of two cohorts. The results may be affected by different sensory experiences, different exposures to environmental contaminants, different medical histories, etc. Estimates of the true magnitude of the decline of sensory functioning over the lifespan require longitudinal data (Murphy et al., 1989).

The methods used to measure intakes (subjective estimation on a visual scale in Study II, weighing left-overs in Study V) were not the most accurate. The subjective estimation of intakes of the yogurt-like oat bran product on a visual scale (II) was imprecise, yielding only rough estimates of the amounts eaten. Moreover, the weighing of left-overs (V) was an indirect measure of intakes, and we only know the quantities that were returned from the house-holds that had received cold cuts. Whether our subjects returned all left-overs and whether they consumed the total amount by themselves, remains unknown. This problem does not concern only the present study, but rather home-use studies in general level, as the evaluation and consumption conditions in home-use tests can not be controlled.

The ad libitum condition had a marked effect on intakes. Moreover, no information is available on subjects' dietary habits or on their physical activity during the test periods. Thus, it is uncertain, whether subjects adjusted their diets taking into account the test food products received or whether they simply added the test food products as an extra energy source to their diet. Because of the limitations listed above, the information on intakes was compromised. The intake measurements should therefore be viewed more as a reflection of acceptance of the test food products than as an accurate indicator of intakes. In keeping with this view, different intake patterns reflecting acceptance of particular foods in the elderly divided based on such background characteristics as olfactory performance, age, and mood can still be discussed.

5.2 Chemosensory performance

5.2.1 Olfaction

Olfactory function was measured with four different tests. The olfactory tests proved to be reliable instruments for measuring olfactory capabilities. All of the tests provided highly significant separation of anosmics, hyposmics and normosmics from each other. The young outperformed the elderly in odor detection, identification, and discrimination. The difference was largest in the odor identification compared to other tasks. Whether these results describe true differences in olfactory capabilities between the young and the elderly is another question. The difference was likely partly due to a cohort effect resulting from cognitive differences between the age groups, as the odor identification task is cognitively demanding, and thus, is affected by both sensory and cognitive factors (Murphy, 1985). In addition, Cowart (1989) has shown an association between education level and performance on psychophysical tests. In the present study, the young population was recruited from the university, while the elderly represented a more general population. Thus, the difference in education level has possibly contributed to the true difference in olfactory performance of the two age groups.

Aging has been shown to take a toll on odor threshold sensitivity (Cain et al., 1990; Stevens and Cain, 1993; Griep et al., 1995), but surprisingly, no difference between the age groups

was found in threshold for n-butanol. This divergent result may be due to threshold tests showing rather poor test-retest reliability, as variation even within subjects has generally been found to be high (Hummel et al., 1997). Thus, to be able to generalize the finding, testing should have been repeated.

Characteristic of the olfactory performance of the elderly was a greater variation in their scores. The increased variation in olfactory performance with age may be the outcome of people aging at different rates physiologically (Hegsted, 1989). Thus, the olfactory performance of a portion of the elderly was as good as most of the young, while age had more deteriorative effect on the olfactory capabilities of some of the elderly. Beauchamp (1990) has speculated that perhaps the maintenance of sensitivity to odors by some of the older individuals is due in part to the regularly exercising these senses, similar to repeated exposure to odors increasing the sensitivity of expert tasters and smellers (e.g. wine tasters, perfumers) to the substance in question. However, constant exposure to odors, e.g. in the workplace, appears to lower rather than heighten sensitivity to those substances (Beauchamp, 1990). In the present study, it is more likely that poor olfactory performance was partly due to the poorer health status of these subjects. An association between health status and olfactory performance was present: the poorer the health, the poorer the odor detection and identification abilities (II, V). An increase in the rate of chemosensory problems has been found to be associated with individuals' overall health status, other sensory impairments, and functional limitations (Hoffman et al., 1998).

5.2.2 Taste

Overall, the young identified tastes better and also rated the tastes as more intense than the elderly. However, the performance was taste-specific; the young identified sour, bitter, and salty tastes better than the elderly, while the elderly were better able to identify sweet taste. The exceptionality of sensitivity to sweet taste was also seen in the suprathreshold intensity ratings, in which the young rated sour, bitter, and salty tastes as more intense than the elderly, while no difference between the age groups was seen in intensity ratings for sweet taste. Previous research also suggests that advancing age does not deteriorate sensitivity to sweet taste as much as to other tastes (Weiffenbach et al., 1982; Cowart, 1989). Gilmore and

Murphy (1989) found that the ability to discriminate caffeine differed significantly between the young and the elderly, whereas no significant difference was observed for sucrose. Some researchers have, however, reported aging to reduce sensitivity to sweetness as much as it does to other tastes (Bartoshuk et al., 1986; Stevens et al., 1995). The studies measuring taste sensitivity have in most cases been conducted using aqueous solutions of taste stimuli. However, Mojet et al. (in press) have shown that measurement of sensitivity to taste stimuli at threshold or suprathreshold level in aqueous solutions may not be related to taste perception in real food products, and certainly not to taste preference. These results suggest that sensitivity measurements in simple aqueous solutions may not be directly exploitable to research considering food perception and preference of the elderly.

One should also bear in mind that the taste test used here was intended to measure taste identification and intensity perception of suprathreshold taste stimuli, and not to cover all aspects of taste acuity. The test did not, for instance, measure the threshold sensitivity. Unfortunately, some of the concentrations proved not to reach the suprathreshold level, being under the recognition threshold for a portion of the elderly. These elderly, thus, had to guess the taste quality. Moreover, although they did not recognize the taste, they were instructed to give it an intensity rating. That may have been frustrating, possibly also affecting the results by producing false positives in the responses.

5.2.3 Chemesthesis

Testing for sensitivity to trigeminal stimuli revealed a stimulus-specific effect. The young were more sensitive to oral cooling from menthol than the elderly, but the two age groups did not differ from each other in perception of oral burning from piperine. The stimulus specificity may, however, result from the difference in the testing methods. Testing for oral burning of piperine was conducted with nose clips attached, while testing for oral cooling of menthol was conducted with the nostrils open. Thus, the latter testing method enabled subjects to use olfactory cues as well; the differences in sensitivity to oral cooling were therefore due to differences in both olfactory and trigeminal perceptions, rather than purely trigeminal perception. As shown by Hummel and Livermore (2002), trigeminal and olfactory systems interact at multiple levels, and the interaction is an important determinant of

sensations of odor. Moreover, Hummel et al. (1996) found that loss of olfactory function also leads to a decrease in trigeminal sensitivity. Thus, the present result indicating a significant difference in the sensitivity to oral cooling between the age groups may not solely reflect a difference in trigeminal sensitivity.

5.3. Odor and flavor perception affected by age group and chemosensory performance

Although the young did not necessarily rate the orthonasal odor and retronasal flavor as more intense than the elderly, the young perceived a larger intensity difference between different aroma concentrations. This is in line with the finding that the elderly have a poorer ability than the young to discriminate between food flavors (Cain et al., 1990). The effects of age were, however, more pronounced on orthonasal odor than on retronasal flavor perception. Young adults have been found to outperform the elderly in discriminating suprathresholds of odors (Enns and Hornung, 1988; Stevens and Cain, 1993) and flavors (Stevens and Cain, 1993). However, these studies have often used model solutions rather than real foods. Mattes (2002) stated that data from studies involving model systems may exaggerate the magnitude of the age effect in sensory changes. Tasting with real foods yields a measurable but smaller difference between age groups (Stevens et al., 1991).

Rating the intensity of a particular flavor stimulus is more difficult in complex food systems than in simple model systems due to the contribution of other flavors. Stevens and Cain (1993) suggested that the perception of flavor in water alone may be a false predictor of a person's ability to perceive ingredients in foods, for which thresholds may be several times higher than in water. Small et al. (1997) concluded that flavor is not represented by a simple convergence of its component sensory modalities, but rather it is processed as a unique sensory experience. Possibly, the elderly have a compensatory mechanism that maintains flavor perception at a reasonable level regardless of losses in chemosensory function. The phenomenon may also be due to changes in the relative importance of the contribution of the different sensory inputs, as an age-related decline in sensitivity does not necessarily occur at the same rate for the different senses (Stevens and Cain, 1993; Schiffman, 1993; Hetherington, 1998). Moreover, the elderly may benefit from the enhancing effect of

nonvolatiles, such as sucrose and salt, on the perception of flavor (Kuo et al., 1993; Noble, 1996).

Although the elderly did not differ markedly from the young in their retronasal flavor intensity ratings, their chemosensory performance did have an effect on flavor perception. The poor function of one chemosensory modality while another modality continued to function normally resulted in unbalanced flavor perception, as seen in Study I. Murphy (1993) suggested that when some of the components in flavor fall below the threshold of an older individual, the flavor may be perceived as less pleasant. The disability to perceive components of food flavor may also be beneficial by suppressing undesired flavor characters (Cain et al., 1990; Wysocki and Pelchat, 1993). However, the flavor component that is not perceived may be just the one that suppresses some unpleasant note of the overall flavor, and thus, the unpleasant flavor component becomes highlighted. Such an experience will most likely lead to a decrease in hedonic response to that particular food. In Study I, the biased perception of flavor was related to a decrease in hedonic responses to the flavored yogurts. However, in Studies II and V, although the elderly rated the flavor intensity of the products as weaker than the young, it had no impact on their hedonic responses. In line with these results, Murphy (1993) suggested that the age effects on preference do not appear to be related to generally lower perceived intensity, but rather the imbalanced flavor perception influences the preferences.

In the research literature considering the elderly, a wide attention has been paid in examining the weakening sensory acuity using validated chemosensory tests and intensity ratings for aqueous solutions of odor or taste stimuli. Until now, the research has, however, not been focused on proportioning such test results on the food-related sensations and preferences of the elderly. The present study tried to forge a bridge between the two separate worlds of chemosensory performance and flavor perception, as well as preference for foods. The results showed that olfactory performance of the elderly on psychophysical tests was moderately linked to orthonasal odor intensity ratings for simple aqueous solutions as well as for more complex systems, e.g. real products. This suggests that good performance in a psychophysical olfactory test leads to a superior ability to orthonasally differentiate between suprathreshold aroma concentrations, while poor olfactory performance results in poor orthonasal intensity differentiation.

However, practically no connection existed between olfactory performance and retronasal flavor perception for real food products. These results support the proposition by Duffy et al. (1999) that the elderly exhibit low sensitivity of retronasal flavor perception despite high sensitivity in orthonasal perception, possibly as a result of oral conditions influencing chewing and mouth movements. Heilmann and Hummel (2004), in turn, suggested that perception of odors through the retronasal route is less effective than through the orthonasal route, possibly related to the functional significance of retronasal odor perception during eating and drinking. Moreover, particular compounds may stimulate both taste and smell systems (Delwiche, 2004), which may be another cause for the discrepancy found between olfactory performance and perception of retronasal flavor of foods/beverages. To conclude, the predictive ability of olfactory performance on retronasal flavor intensity ratings was not ecologically valid when it came to flavor perception of a real food or beverages.

5.4 Food acceptance and preferences of the elderly

The elderly were less responsive to changes in flavor intensity, as reflected by their hedonic responses. In other words, the range for tolerated variation in flavor is wider for the elderly than for the young. This has been speculated to result from the poorer ability of aged individuals to discriminate between flavor levels (Cain et al., 1990). However, the flavor intensity ratings in this study showed that the elderly did perceive a difference in the flavor intensity between the samples. The weaker responsiveness may therefore be due to differences in response behavior, as discussed earlier. Lesser responsiveness can also be seen in the remarkable stability of food likings among the elderly despite their diminished sensory abilities that alter flavor perception. Reasons for the stability can be numerous. Mojet et al. (in press) have proposed that the stability of preferences is due to a changed internal representation or mental image of food products. The recent findings of the existence of central neural integration of taste and smell inputs support this point of view. The observation of Dalton et al. (2000) on the cross-modal summation of subthreshold concentrations of selected compounds could be daringly interpreted as the elderly having a compensatory mechanism that maintains flavor perception regardless of losses in chemosensory function. Hence, via integration of sensory modalities, the overall flavor perceived changes little, but does not lead to altered preference.

Another explanation for the rather small differences in food acceptance between the elderly and the young is that chemosensory changes develop gradually, thus allowing the elderly subjects to adapt to the altered flavor of foods and adjust their diet (Rolls, 1992; Wysocki and Pelchat, 1993; Murphy, 1993). Although some researchers (Mattes and Cowart, 1994; Temmel et al., 2002) have found that complaints of olfactory loss are predominantly food-related, the number of complaints appears to be associated with duration of olfactory dysfunction. Hence, the longer the dysfunction has been present, the fewer the complaints. The onset of hyposmia or even anosmia in most of the elderly occurred long time ago, and thus, its impact on flavor preferences has decreased over time. It has been difficult to document loss of food enjoyment in noninstitutionalized elderly (Stevens, 1989). However, the elderly living in institutions complain about their food frequently. This raises the question of whether the reason behind the complaints is an actual difference in the sensory properties and quality of food provided in institutions relative to the diet of independently-living individuals (Mattes, 2002). Alternatively, the institutionalized elderly are likely to suffer more frequently than their independently-living, subjectively healthy counterparts from states that might affect food acceptance and intakes such as chemosensory losses (de Jong et al., 1999), different diseases (Thompson and Morris, 1991), and depression (Thompson and Morris, 1991; Morley and Kraenzle, 1994).

Besides the age-related chemosensory changes, mood states affected the food acceptance as well, that is, the negative mood decreased the hedonic responses. The present study gave only a hint of the role of mood states in the food acceptance and intakes of the elderly, and no far reaching conclusions based on that can be made. However, it would be important to take the mood states into account in the research concerning the elderly people. Equally important is to take into account the health status of the elderly, as it have been shown to have an effect on food acceptance measured by intakes (II) as well. The reasons behind the food acceptance of the elderly are multiple, and many interactions between the different factors like chemosensory acuity, health, mood, etc. occur affecting the outcome. Hence, it is important not to underestimate or bypass any of these factors.

In Study V, the people representing the extremes of the age span within the elderly group showed totally different hedonic responses to the food products. One explanation for this may

be the different circumstances in which the food preferences of 60-year-olds compared with 80-year-olds have developed, not to mention those of young adults in their 20s or 30s. The availability of foods has been quite different for these groups, which probably affected their responses to foods and eating in general. Birch (1999) summarized results of studies by Davis (1933, 1939) on the development of preferences in early age; in addition to the predisposition of children to respond to novel foods in systematic ways and to prefer some tastes over others, they were also predisposed to develop a preference for foods available to them. Similarly, the elderly and young adults have learned to prefer foods that are readily available. In addition, the availability of foods has been totally different between the 'young-old' and the 'old-old' within the elderly group as well as between all elderly and the young adults, causing differences to appear in hedonic responses.

Thus, people's food preferences rely strongly on their earlier food experiences and eating habits. The influence of previous exposures to certain foods is likely to be even more pronounced in the elderly, as their food history goes back further than that of young adults. According to Issanchou (2004), elderly individuals may be more willing to maintain old food habits despite possible alterations in flavor perception than to seek new flavor experiences to compensate for their chemosensory dysfunction. Birch (1999) emphasizes that priority should be given to food preference studies that compare development of food preferences across different environments, as the effects of food environment may be of fundamental importance on the development of preferences. This can be interpreted to mean that one cannot say much about age-related changes in food preferences based on cross-sectional studies. To conclude, nothing is yet known about what part of the difference in food preferences between age groups occurs as a result of aging and what part as a result of earlier food history. Most likely, both of these have an influence since preferences tend to be a complex phenomenon. The complexity certainly does not decrease as people grow older.

5.5 Food intakes of the elderly

Despite scant evidence, the sensory, nutrition, and gerontology literatures are replete with references to an important role of chemosensory changes in food selection and decreased intakes. In this study, olfactory performance affected food intakes, but the effect was dependent

on the food product. Poor olfactory performance decreased intakes of fermented oat bran snack products, while overall intakes of cold cuts were higher in hyposmic subjects. Mattes (2003) states that over 85% of hyposmic patients maintain a stable body weight subsequent to onset of the disorder. Of the patients, 10.6% lose 10% of their weight, while 1.5% gain a similar amount. In the present study, hyposmic subjects may have increased their intake of cold cuts as a behavioral response to loss of sensory satisfaction from food. Anosmia and hyposmia have been observed to be associated with obesity in the elderly. The higher food intake of people with olfactory losses has been proposed to result from the attempt to gain the pleasure out of eating, regardless of the bland flavor (Ferris and Duffy, 1989; Hunter-Smith et al., 1996). The higher intake of cold cuts was observed in both conditions and for all samples, which implies that intensification of flavor was not the reason for the higher intake. Moreover, the importance of familiarity and earlier food habits in predicting intakes was seen in the condition in which a variety of cold cuts was provided.

The elderly with a poorer health status ate smaller amounts than their healthier counterparts. According to the literature, alongside aging, different diseases manifest that affect appetite, and the risk of developing anorexia of aging increases. However, the elderly participating in this study were independently-living, active, and subjectively healthy individuals, while anorexia among the aged is more common in institutionalized persons. Unexplained losses in food intake and body weight occurring near the end of life are characteristic of this syndrome (Horwitz et al., 2002). Mattes (2002) proposed that procurement of adequate nutrition is so central to survival that multiple redundant mechanisms have developed to ensure success. Thus, an alteration or failure of one contributor, such as sensory function, may prompt compensation by others.

5.6 Flavor enhancement as a tool for increasing the hedonic value of foods

The findings underlined the success of flavor enhancement being strongly dependent on the type of added flavor. Addition of smoke aroma decreased liking, while adding pepper mix had no influence. The addition of a flavor that already exists in a product does not necessarily lead to increased liking among the elderly (Popper and Kroll, 2003). Generally, it is difficult to achieve a well-balanced flavor by adding just one ingredient. Given the heterogeneous

effect of aging on chemosensory perception, especially sense of smell (Wysocki and Gilbert, 1989), the addition of a particular aroma may even emphasize the imbalance of the overall flavor, having a negative impact on liking.

Flavor enhancement did not increase the hedonic value of food among the elderly in general, nor did poor olfactory capabilities lead to liking for the stronger flavor. Moreover, flavor enhancement did not increase, but rather decreased elderly people's intakes of the food products used in this study. The results thus indicate that amplification of food flavor may not be necessary to increase food acceptance among the elderly, at least when it is a question of independently-living, active individuals. Instead, the elderly may profoundly enjoy the pleasures of food and drink, although their perception of food flavor undergoes changes. This conclusion is in line with the observations of Stevens (1989) and Issanchou (2004).

The contradictory results on the effects of flavor enhancement on liking and intake cast doubt on the benefit of flavor-enhanced food. Evidence of the effectiveness of supplementation has thus by far been rather limited. The few studies in which it has functioned in the desired way by increasing either food acceptance or food intake among the elderly (Table 2) are not convincing. First, the increase in food intakes reported by Schiffman and Warwick (1993) was only significant for 3 of 20 foods. Moreover, two of these foods (gravy, syrup) were not nutrient-dense. Second, in a recent long-term trial with institutionalized elderly (>65 years) by Mathey et al. (2001), the energy intake declined less in a group receiving flavor-enhanced meal daily than in a same-aged control group. Given that the energy intake decreased in both groups, it was odd that those receiving flavor-enhanced meals gained weight during the study period.

Considering earlier findings in the area as well as our results, it is astounding that researchers in the sensory and nutrition field have been so convinced of the benefit of flavor enhancement. The method has regularly been proposed as a cure for nutritional problems that occur among the elderly (e.g. Schiffman and Warwick, 1988; Schiffman and Warwick, 1993), even though a causal relationship between chemosensory function and food intakes has not been proven. Moreover, poor chemosensory acuity in elderly subjects in these studies has merely been an assumption, as it has not been measured. Those who have measured the

chemosensory function (e.g. Michon and Delahunty, 2003; Rousseau et al., 2003; Gourillon et al., 2003) have found either a very weak or no association between impaired chemosensory capabilities and liking of intensified food flavor. In conclusion, flavor enhancement has only a limited effect on increasing food liking, not to mention on food intakes, in the elderly population, at least at a nutritionally relevant level.

6 CONCLUSIONS

Age-associated changes in chemosensory function on the food acceptance and intakes seemed not to be as significant as expected based on earlier suggestions. The present study consolidated the earlier suggestion that age effects on food acceptance or preferences do not appear to be related to generally lower perceived intensity, but rather to imbalanced flavor perception. The imbalanced flavor perception, in turn, is related to variation in the magnitude of deterioration in chemosensory capabilities across different sensory modalities.

Along with age-related chemosensory changes, mood states and health status both had an effect on food acceptance of the elderly. Poor health status and negative mood states were related to decrease in hedonic responses. Together with the present results, though exiguous, and the findings in the earlier studies, one can conclude that the role of mood and health status should be taken into account in future research concerning the food acceptance of elderly people. The reasons behind food acceptance of the elderly are complex, and many interactions between such factors as health, mood and chemosensory acuity occur, affecting the outcome.

The olfactory function of the elderly subjects had contrary effects on their intakes. Compared to normosmics, hyposmics ate either significantly more or significantly less, depending on the product. Given the contradictory results of the present study, as well as the fact that according to present knowledge, no researcher has been able to show a causal relationship between diminished chemosensory acuity and decreased food intakes, one can conclude that nutritional problems of the elderly may not be linked to deteriorated chemosensory function. Nutritional problems seem to occur more frequently in the institutionalized elderly rather than in their independently-living, subjectively healthy peers. Institutions taking care of elderly people should direct attention to providing a comfortable eating environment, including a quiet and stress-free atmosphere, eating companionship, and familiar, favorite foods. Unfortunately, unexplained losses in food intakes and body weight, that is, anorexia of aging, may be an inevitable phenomenon that occurs near the end of life.

The olfactory tests used in these studies were considered to be valid for clinical evaluation of olfactory capabilities, as they separated anosmics, hyposmics and normosmics with highly significance. Moreover, the olfactory tests as well as the other chemosensory tests showed that the elderly performed poorer than the young. In the odor identification tests, in particular, the difference between the age groups was so large that it possibly did not reflect the true differences in the olfactory capabilities of the two age groups. Cognitive factors, a cohort effect, and a ceiling effect probably also affected the results.

The ability of the olfactory tests to predict suprathreshold ortho- and retronasal ratings was moderate for simple aqueous solutions. However, the predictive ability was poor when it came to retronasal intensity ratings of a real food and beverages. As the relationship between performance on standardized olfactory tests and flavor perception of food/beverages was weak, the benefit of using such tests in food acceptance studies is debatable. However, the research on the subject is scarce, and thus, no definite conclusions can be made.

Flavor enhancement did not increase the hedonic value of foods, but rather decreased it for some foods. In light of the findings here, flavor enhancement seems unnecessary for ensuring enjoyment and sufficient intake of food in subjectively healthy, independently-living elderly individuals. Since differences in the optimal levels of flavor between the elderly with impaired olfactory function and those with normal olfactory function are rather small, enhancement of food flavor does not appear to offer a distinct advantage. Moreover, since sensory losses occur over a period of many years, the elderly apparently adapt to the bland flavor. The elderly may also have some underlying compensatory mechanism for impaired olfactory perception. The compensation may come via other sensory modalities (taste and trigeminal) or the elderly may learn to utilize the remaining sensory capabilities more effectively to maintain their enjoyment of food, even if the flavor deviates from that they were used to.

The rapidly growing population of the elderly requires a proactive approach from the food industry and food service companies. The modification of foods may not be as essential as determining the eating habits of the elderly since these are a strong driver of their preferences, as they are for other age groups as well. Moreover, to get more complete picture of the food-related issues of the elderly, qualitative methods should be employed in research. Furthermore, longitudinal data are needed to determine the actual age-related differences in food acceptance and food preferences, without the interference caused by the cohort effect.

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8 APPENDIX A (ORIGINAL PAPERS I-V)