# Food perception and food liking with age

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Dit onderzoek is uitgevoerd binnen de onderzoeksschool VLAG
(Voeding, Levensmiddelentechnologie, Agrobiotechnologie en Gezondheid)

# Food perception and food liking with age

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Proefschrift

ter verkrijging van de graad van doctor
op gezag van de rector magnificus
van Wageningen Universiteit,
Prof. dr. M.J. Kropff,
in het openbaar te verdedigen
op vrijdag 28 april 2006
des namiddags te 13:30 uur in de Aula

Kremer, Stefanie
Food perception and food liking with age
Thesis Wageningen University - with references - with summary in Dutch and German

ISBN: 90-8504-418-9

Für mein Omchen (1906-2001)

**Kremer, S. (2006) Food perception and food liking with age**
*PhD thesis, Wageningen University, The Netherlands*

Keywords: elderly, sensory acuity, taste, olfaction, irritation, compensation, just noticeable difference (JND), conjoint analysis, integrated product concept

The elderly population is rapidly growing worldwide. Food intake and also body weight both tend to involuntarily decrease in people aged 65 years or older. Since weight loss in later life is associated with frailty and increased morbidity, adequate dietary intake has been recognized as one of the key factors in maintaining good health and in increasing the quality of life of the elderly. In sensory and nutrition research, age-associated losses in sensory function are believed to change the perception of food, to decrease food liking and consequently to decrease food intake of the elderly, although data in support of this line of assumptions are currently scarce. Consequently, there is a growing need to understand more about age related changes both in food perception and food liking. What changes are seen in the later years of life and what are the implications of these changes?

The present thesis describes research on food perception, food liking and sensory acuity with increasing age. Perceived intensities and pleasantness are measured in "real-life" food products for the same group of healthy elderly and young subjects. The food products used in the studies (soups, sweet & savoury waffles, tradtional & novel custard desserts, novel tomato health drinks) are experimentally varied in their flavour, texture and/or irritation according to full-factorial designs. The sensory acuity of the subjects is assessed by means of sensitivity tests for the different sensory modalities (taste, olfaction, oral texture, irritation).

The elderly perceive foods differently compared to the young, mainly as less intense in flavour and in creaminess/fattiness. These age differences may originate from changes in the sensory systems of the elderly at peripheral or central level or both. Possible changes at the peripheral level are anatomical changes in the olfactory system, reduced mastication due to dentures, and decreases in total number of sensory receptor cells and/or a diminished saliva/mucus production. Changes in the signal-to-noise ratio at neural or perceptual level may be put forward to explain the age difference at a more central level. However, food liking is not reduced in the elderly, despite age-related changes in perception. To account for this missing link two hypotheses may be postulated. Firstly, sensory and hedonic information is processed in different regions of the brain. Thus, intensity perception may vary between the elderly and the young, while the hedonic aspects remain largely stable with increasing age. Secondly, as people grow older, they may learn to associate the foods they like with the reduced sensory signals and thus they may not experience a decrease in food liking.

It is concluded that decreased sensory acuity, although causing losses in perception of the elderly, is obviously not causing a reduced food liking and thus cannot be the predominant reason for a diminished food intake. Non-sensory strategies taking other age-related factors into consideration - such as food wanting, loneliness, depression, reduced social interaction - may prove to be even more successful in increasing food intake and should be pursued in future research because an adequate dietary intake remains one of the keys to healthy ageing.

# Contents

# Chapter 1

# Introduction

## The elderly population

Europe, Asia and the United States are undergoing a demographic shift manifested by a growing elderly population. The share of people over 60 is presently about 15 percent in the EU, China, Japan and US. According to the latest demographic calculations, this share will have almost doubled by 2050 in the EU (28%), China (30%) and Japan (30%), while growing more modestly in the US to reach 21% at the end of the period. Furthermore, the elderly population itself is aging. The oldest old (80 years or older) are the fastest growing segment of the elderly population. This subset currently makes up 11 percent of the elderly population and will grow to 19 percent by 2050. The number of centenarians (aged 100 years or older) is also projected to increase 15-fold from approximately 145.000 in 1999 to 2.2 million by 2050 worldwide (United Nations, 2002).

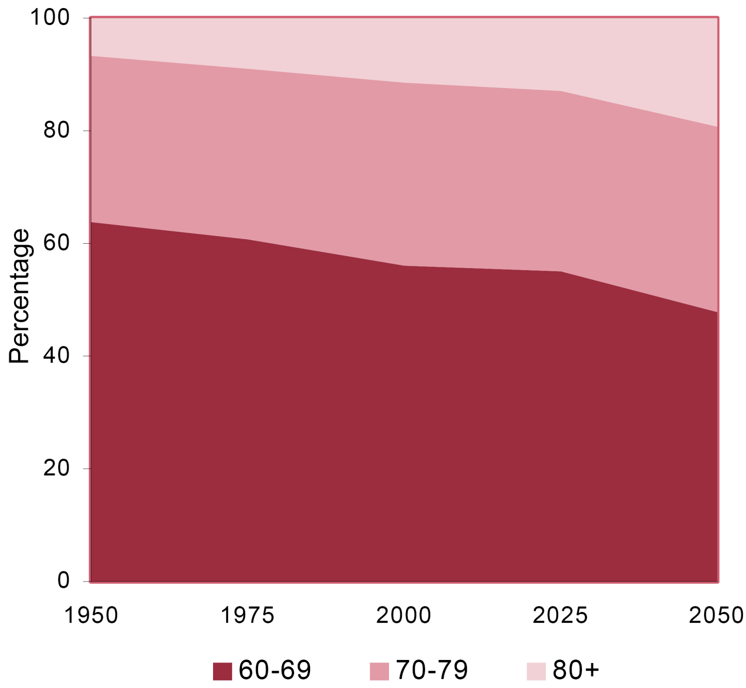


*Figure 1. Distribution of population aged 60 or over by age groups: world, 1950-2050.*

People age at different rates, implying that the elderly population is highly heterogeneous. The term "successful aging" refers to elderly individuals that are healthy, live independently and exhibit little or no loss in their functioning in contrast to elderly individuals that suffer form a variety of medical conditions, diseases and/or disabilities, and consequently reside in nursing homes (Rowe & Kahn, 1987; Strawbridge et al., 2002).

Food intake and also body weight both tend to involuntarily decrease in people aged 65 years or older, even in healthy individuals (Fischer & Johnson, 1990; Lehmann & Bassey, 1996; Morley, 2001). Since weight loss in later life is associated with frailty and increased morbidity (Mowe & Bohmer, 1996), adequate dietary intake has been recognized as a key factor in maintaining good health (Sullivan, 1995; Morley, 1997) and to generally increase the quality of life of the elderly (Vetta et al., 1999).
The prevalence of sensory impairment among the elderly is reported to be high and to increase with age (Klein et al., 1991; Cruickshanks et al., 1998; Murphy et al. 2002). These age-associated losses in sensory function are believed to affect food perception, to decrease food liking and consequently to modify food choice, although data in support of this "sequence of assumptions" are currently lacking (Mattes, 2002). Consequently, there is a growing need to understand more about age-related changes both in food perception and food liking. What changes are seen in the later years of life and what are the implications of these changes?
In this general introduction, a brief overview will be given of age-related changes in cognitive ability, in food perception and in food liking. Subsequently, a brief description of the EU-funded HealthSense project will be given. Finally, the outline of the objective and the structure of this thesis will be sketched.

## Age-related changes in cognitive ability

During normal aging there is a gradual and progressive loss of cognitive performance by the brain (Keller, 2005). These age-related changes are most pronounced in tasks that require a high degree of cognitive control, such as when attention must be intensely focused in the face of distraction (Duchek et al., 1998), when information must be maintained in an easily accesible form within working memory (Zacks et al., 1996) or when tasks must be performed that rely on explicit learning and/or explicit memory (Small, 2001). Interestingly, in incidental and implicit learning or memory tasks the elderly perform just as well as the young (Hoyer and Lincourt, 1998, Möller et al., in press).
Various hypotheses have been put forward to explain these age-related deficits in cognitive performance. Firstly, a general slowing down of the processing-speed with increasing age has been suggested (Cerella, 1985). Secondly, a reduction of the working-memory capacity that slows down the decision making of the elderly and decreases their proportion of correct answers in self-ordered pointing tasks (Daigneault & Braun, 1993). Thirdly, deficits in the inhibition of inappropriate response tendencies make it

more difficult for the elderly to filter relevant from irrelevant information (Zacks et al., 1996).

A high degree of variablity has been observed with regard to the severity of cognitive impairment in the elderly. While some elderly display declines in cognitive performance, others maintain performance levels similar to those of younger age groups (Keller, 2005).

## Sensory perception

In human perception, sensory systems perform a variety of common tasks such as vision, hearing, touch, vibration, pain, taste and smell. Each system employs peripheral receptors that respond to specific energy in their environment, it integrates the information received from those receptors, it transmits information to central structures using a neural code, and it eventually compares the results with sensations received previously and those derived from other sensory systems (Hudspeth & Logothetis, 2000).

Food perception does not usually depend on a single effect by one stimulus of one sensory modality. Instead, it is the result of simultaneous stimulation of at least three sensory systems: the gustatory, the olfactory and the somatosensory system. Recent neurological evidence supports the idea of the convergence of sensory information from different sensory systems. Cerf-Ducastel et al. (2001) clearly demonstrated that gustatory and oral somatosensory inputs converge in the brain, namely in the insular lobe and the opercular part of the frontal, rolandic and temporal gyri. Multi-sensory approaches to perception are already well known in the related fields of vision and audition research (Driver & Spence, 2000), where cross-modal integration of sensory information is thought to be the rule, rather than the exception.

The general structure and most of the facts in the following overview of the gustatory, olfactory and somatosensory system are rather directly borrowed from the excellent review of Bear, Connors, and Paradiso (2001) who are experts in the fields of neuroanatomy, physiology and molecular biology, whereas the present author, who is very much indebted to them, is not.

### *The gustatory system*

Taste-sensitive areas - called papillae - are spread over the surface of the tongue. Within these papillae are the taste buds, and within the taste buds the taste receptor cells can be found (Figure 2). In addition, extra-papillary taste buds are also distributed throughout the pharynx and upper part of the oesophagus.

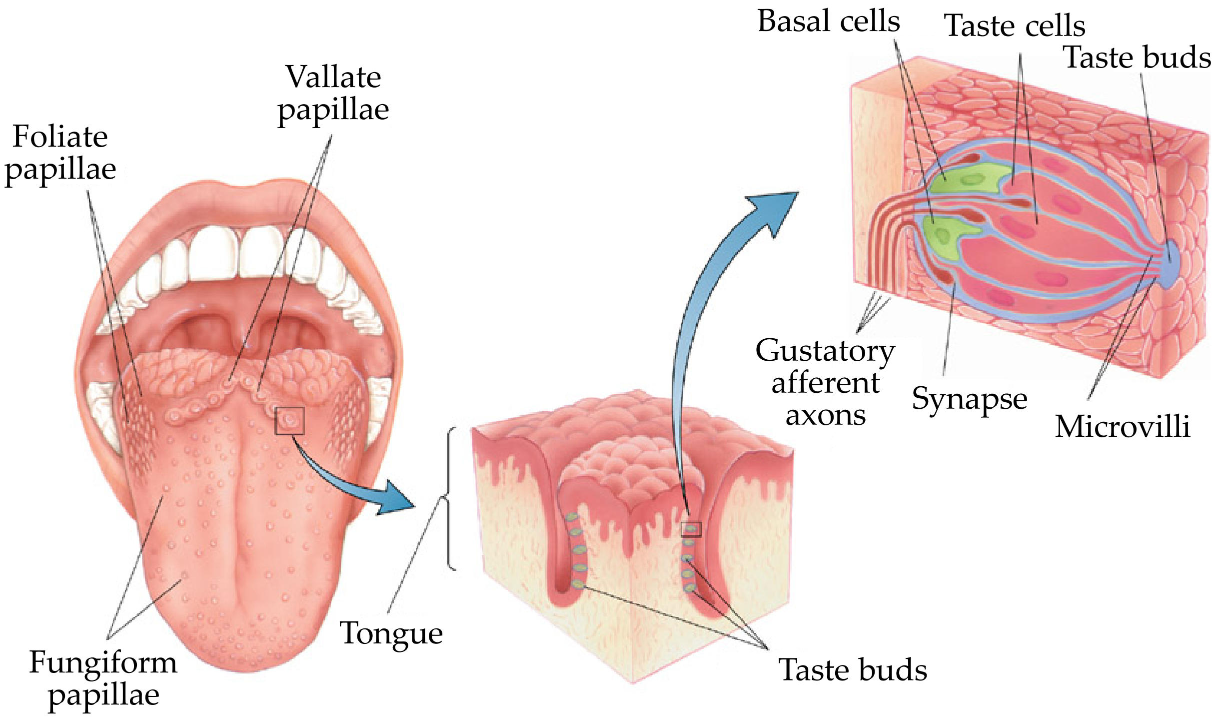


*Figure 2. The tongue, its papillae, and its taste buds (Bear et al., 2001). © Lippincott Williams & Wilkins.*

Taste stimuli are soluble in water/saliva, during food ingestion they travel through the salivary secretions and mucus and once they reach the taste buds they interact with the taste receptor cells. Taste buds are located just below the epithelial surface. The taste receptor cells in these buds have an elongated shape proliferating into cilia, which are accessible through epithelial pores, often called "taste pores". These taste receptor cells have a high turnover rate with a lifespan of approximately 10 days. Several transduction (= the process by which an environmental stimulus causes an electrical response in a sensory receptor cell) mechanisms have been described for taste. They can be separated into two main categories. Firstly, ionic mechanisms relying directly on ionic flux through channels in the taste-cell membrane and secondly, second-messenger mechanisms that are initiated by extracellular binding of taste substances to specialized proteinic receptors. Sodium chloride tasting is an example of the ionic type and tasting sweet and bitter tastes are examples of the second type.

The neural taste pathway goes from the taste receptor cells, to the primary gustatory afferent axons, and then proceeds into the brain stem. Three cranial nerves (the chorda tympani (VII), vagus (X), and glossopharyngeal (IX)), containing primary gustatory axons, innervate different areas of the tongue and bring taste information to the brain. The gustatory axons of these nerves all enter the brain stem, bundled together, and synapse within the nucleus of the solitary tract in the medulla. From this gustatory nucleus, taste pathways diverge. One of these pathways runs through a nucleus in the thalamus where the thalamic neurons project to the primary taste area in the cerebral cortex. The other pathway runs to the amygdala and the hypothalamus, regions that have been linked to influence the emotional responses to oral sensations and to regulate appetite.

### *The olfactory system*

The olfactory area is a relatively small area in the upper nasal passages and it is composed of a mixture of olfactory and respiratory epithelium. As olfactory receptor cells are nerve cells rather than epithelial cells, the term "olfactory epithelium" is in fact wrong. However, the term was introduced long ago and before this was recognized. Only the olfactory epithelium is responsible for odour perception and it consists of three cell types: ciliated olfactory receptor neurons, supporting cells and basal cells.

Odorous molecules dissolve in the olfactory mucus layer and contact the cilia of the olfactory receptor neurons (ORNs), which are responsible for the olfactory signal transduction. Each ORN expresses only one type of olfactory receptor (OR) and ORNs with the same receptor type are scattered randomly within one of four spatial zones in the olfactory epithelium (Ressler et al., 1993; Vassar et al., 1993). ORNs have a high turnover rate with a lifespan of approximately 3 to 7 weeks.

Each ORN in the olfactory epithelium sends a single axon, through tiny holes in a bone - the cribriform plate - to the bottom layer of the olfactory bulb of the brain.

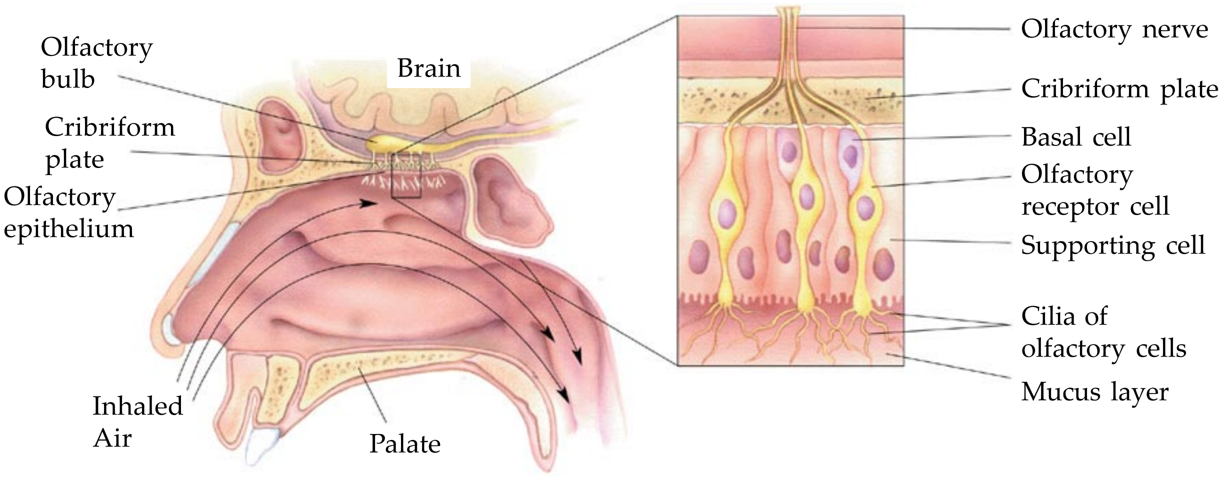


*Figure 3. Location and structure of the olfactory epithelium (Bear et al., 2001). © Lippincott Williams & Wilkins.*

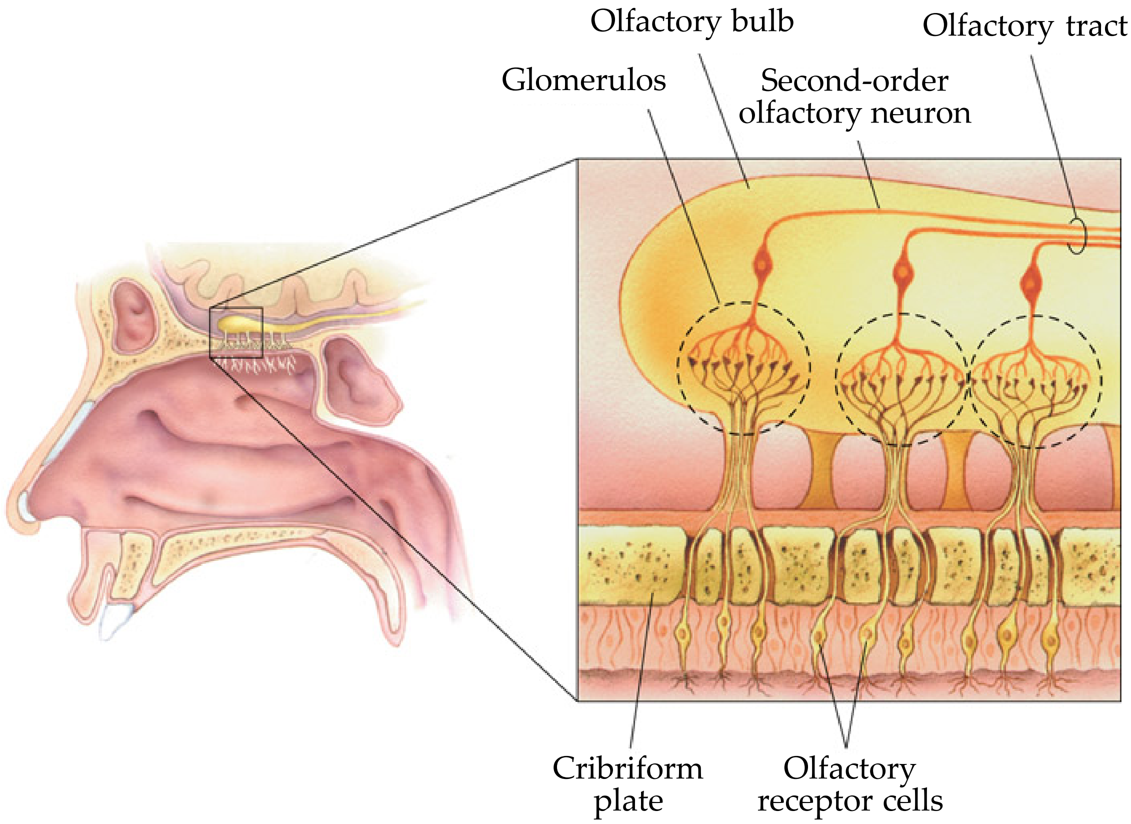


*Figure 4. Structure of an olfactory bulb (Bear et al., 2001). © Lippincott Williams & Wilkins.*

The olfactory bulb is located in front of and below the main mass of the brain, and its dendrites of neurons (mitral cells) form complex clusters of connections (glomeruli) with the axons of the many different ORNs. Signals from 5000 or so ORNs with the same OR converge on two topographically fixed glomeruli, thus transforming sensory information that is randomly scattered within one of four broad zones in the olfactory epithelium into a stereotyped sensory map in the olfactory bulb (Vassar et al., 1994; Ressler et al., 1994). Remarkably, glomeruli of ORNs expressing the same OR type are not only located at bilaterally symmetrical positions in the two olfactory bulbs but also at approximately the same positions - within a 95% confidence interval - in the olfactory bulbs of different individuals (Schaefer et al., 2001). Consequently, the bulb map is virtually identical in all individuals in a species and remains constant over time (Buck, 2005; Axel, 2005). This structure of the olfactory bulb is thought likely to be important for at least two aspects of olfaction (Buck, 2005). Firstly, through a high degree of signal integration it helps to maximize the sensitivity to low odour concentrations. Secondly, since ORNs are short-lived and are continuously replaced, the bulb map keeps the neural code for an odour intact, assuring that odorants can elicit memories.

Several different classes of olfactory bulb neurons project the output of the olfactory bulb to the primary olfactory cortex, which is located below the anterior portion of the temporal lobe (Gottfried et al., 2002). From this primary olfactory cortex the neural pathways become extremely diverge, including projections to the thalamus and to structures in the limbic system, the latter are involved in the experience of emotion and memory.

### *The somatosensory system*

The somatosensory system transmits information about four sensory modalities: touch, temperature, pain and proprioception (body position). There are different receptors for each modality: mechanoreceptors, thermoreceptors, nociceptors and proprioceptors. Mechanoreceptors mediate the sensation of touch by responding to the physical distortion of the body or tissue. Several types of mechanoreceptors are known, including free nerve endings, Merkel's disks, Meissner's corpuscles, Pacinian corpsuscles, Ruffini endings and the hair follicle receptors.

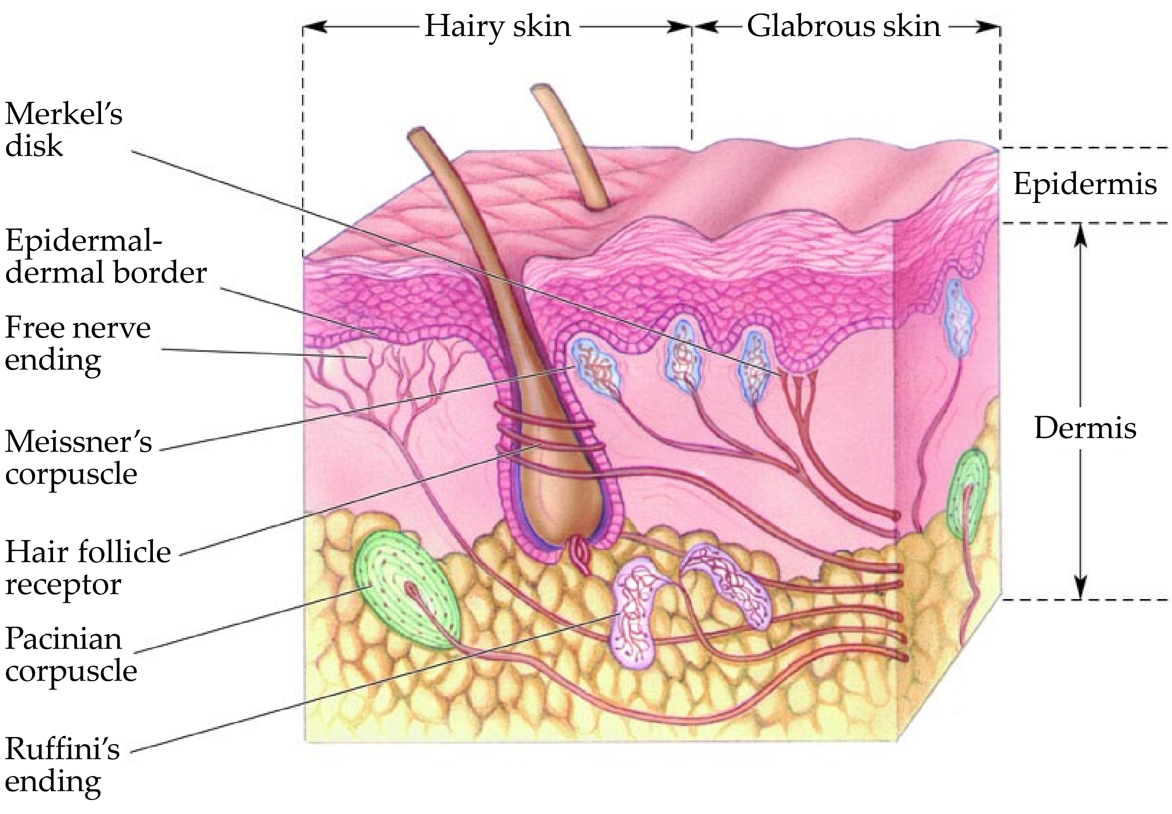


*Figure 5. Somatic sensory receptors in the skin (Bear et al., 2001). © Lippincott Williams & Wilkins.*

Each of these mechanoreceptors responds to different types of stimuli with varying receptive field size. Thermal receptors detect changes in the temperature of the environment. Separate receptors mediate the sensations of heat and cold. Nociceptors mediate the sensation associated with painful stimuli and they are mostly free nerve endings. Proprioceptors provide information about the location of the body (joints and muscles) in space. The oral cavity is the area of the human body where somethetic receptors are most densely located, causing it to be most sensitive to somatosensory stimulation (Van Boven & Johnson, 1994).

The neural somatosensory pathway goes from the somethetic receptors to the brain through primary afferents. The primary afferents have cell bodies in the dorsal root ganglia and enter into the dorsal spinal cord. They synapse upon neurons within the spinal cord, although the large axons also branch to carry information directly to the brain. Somatosensory information is segregated into two general pathways that project to different parts of the brain. Firstly, the dorsal columns pathway carries information about touch and limb position. Secondly, the spinothalamic pathway carries information about pain and temperature through the spinothalamic tract.

The peripheral neurons synapse on neurons within different regions of the thalamus and from there, neurons project to the primary somatosensory cortex in the precentral gyrus.

## Age-related changes in perception

With increasing age - beginning around age 40 - perceptual and sensory function changes towards a decreased functioning, as sensory receptors age and neural efficiency drops (Corso, 1981). The following observations have been made with respect to age-associated changes in sensory performance. Neural responses generally slow down with aging (Salthouse & Lichty, 1985; Salthouse, 1996) and this might be accompanied by an increased persistence of the stimulus in the neural representation (Cremer & Zeef, 1987; Raz et al. 1990). The elderly demonstrate slower reaction times to stimuli (Stern et al., 1980) and they have more difficulties in stimuli identification once the stimuli arrive in rapid succession (Birren et al., 1980). The more complex a sensory task is the more apparent is this slowing down of the neural responses in the elderly (Cerella et al., 1980). Furthermore, it becomes more difficult for the elderly to control the sensory information that enters and is sustained in their short-term memory (Johnson et al., 2002) and to divide attention between various sensory inputs or stimuli (Wright & Elias, 1979).

## Taste perception with age

It is unclear, whether and also to what extent the perception of taste diminishes with age. Roughly half of the researchers did find diminished sensitivity with age for at least one taste quality when the tastants were dissolved in water (Schiffman et al., 1981; Stevens et al., 1984; Chauhan & Hawrysh, 1988; Murphy & Gilmore, 1989; Schiffman et al., 1994; Drewnowski et al., 1996; Mojet et al., 2003). However, most authors found no or little age effect once the tastants were embedded in food products (Little & Brinner, 1984; Warwick & Schiffman, 1990; Zallen et al., 1990; De Graaf et al., 1994; Drewnowski et al., 1996; Mojet et al., 2003). Moreover, in studies in which taste intensities were assessed in aqueous solutions as well as in product, only poor correlations were found between the results for the two different conditions (Drewnowski et al., 1996; Mojet et al., 2003).

The structural basis of impaired taste perception in normal aging is poorly understood. Not many anatomical changes have been observed in the taste system with aging (Seiberling & Conley, 2003). In the past it was thought that taste loss with increasing age was caused by a decrease in the overall number or density of taste papillae or taste buds (Mistretta, 1984). However, this view has been changed in the light of other studies that, using more precise techniques, found very little or no loss of taste buds (Seiberling & Conley, 2003). The possibility remains that age-related taste impairment arises from changes in the replacement rate of taste cells or from changes in the taste cell membrane i.e. ion channels and receptors (Weiffenbach, 1991; Osada et al., 2003; Fukunaga, 2005). However, recent work has indicated that once a nose-clip blocked the olfactory input, more than two-third of the age differences in supra-threshold taste perception disappeared (Mojet et al., 2003; Mojet et al. 2005a). The authors concluded that the young make use of their sense of smell in taste perception and that the elderly, due to olfactory impairment (see below), do so to a lesser extent. Thus, reported impairment of taste perception with age might largely be caused by age-related losses in olfaction.

## Olfactory perception with age

The impairment of olfactory perception as a result of ageing has been described by a number of authors for both aqueous solutions and food products. The elderly perceive the odours not only as less intense (Murphy, 1983; Stevens & Cain, 1987; De Graaf et al., 1994; Philipsen et al., 1995), they also experience more difficulties in odour identification and discrimination (Doty et al., 1984; Cain et al., 1990; De Wijk & Cain, 1994; Lehrner et al., 1999; Larsson et al., 2000). Under continuous odour exposure, elderly are more prone to olfactory adaptation and their sensitivity recovers slower than that of young subjects (Stevens et al., 1989). Finally, measurements of brain activity in response to olfactory stimulation -olfactory event-related potentials (OERPs) - further support the psychophysical findings of impaired smell perception in the elderly (Murphy et al., 1994; Covington et al., 1999). The elderly were found to have smaller amplitudes and longer latencies than the young. Nevertheless, it cannot be completely ruled out that smaller amplitudes and longer latencies might be a general characteristic in the elderly, rather than a sign of specific deterioration.

The structural basis of impaired olfactory perception with increasing age might be explained by the following age-related changes in the olfactory system at both peripheral and central levels. Firstly, in the olfactory area the surface of the olfactory epithelium decreases in size with increasing age (Paik et al. 1992). Secondly, the density and complexity of adrenergic innervation within the lamina propria of the olfactory mucosa decreases with increasing age (Chen et al., 1993). Thirdly, the calcium binding protein elements are decreased in the olfactory epithelium of the elderly, which makes the olfactory receptor neurons more vulnerable to calcium mediated cell death (Yamagashi et al., 1996). Fourthly, within the olfactory bulb the number of mitral cells decreases from about 60,000 cells at the age of 25 to about 14,500 at the age of 95 (Bhatnagar, et al., 1987). Fifthly, olfactory nerve fibres become misrouted with increasing age i.e. they enter deeper parts of the olfactory bulb and form glomeruli outside the glomerular layer (Hoogland et al., 2003). Sixthly, neuropathy in brain regions that contribute to olfactory information processing (i.e. hippocampus, anterior olfactory nucleus, entorhinal cortex) is reported in healthy older adults (Price et al., 1991).

Furthermore, the olfactory bulb is one of the sites in the human brain where early changes appear that are related to neurodegenerative diseases such as Parkinson's and Alzheimer (Kovacs et al., 2001; Katzenschlager & Lees, 2004). In summary, olfactory impairment as a result of aging seems to be multifactorial, with changes seen in the composition of the olfactory epithelium, in cell numbers, in the cilia function, and intracellular changes as well as neural responses.

### Oral somatosensory perception with age

Little is known about the effect of age on oral tactile and/or temperature perception. Ageing modifies various aspects of oral physiology such as dental status, bite force, saliva composition or muscle fatigue (Ship, 1999), which in turn may influence somatosensory perception. Dental status and oral health are assumed to be the factors with the highest impact on oral tactile perception as dental integrity is directly related to masticatory performance. Elderly, especially those with partial or complete dentures, suffer from impaired masticatory efficiency (Heath, 1982; Wayler et al. 1984). However, healthy elderly easily compensate reduced masticatory efficiency by changing their chewing behaviour, such as increase of chewing frequency and duration (Kohyama et al., 2002; Mioche 2004). Furthermore, other oral sensations, such as vibratory and thermal sensations, were found to remain relatively stable with aging, showing only a slight decline in function after age 80 (Calhoun et al., 1992) and no significant age-associated deterioration was observed in spatial acuity of touch sensations in the anterior tongue (Fukunaga et al., 2005). Thus, it seems that oral tactile and temperature perception is relatively well preserved in the elderly.

The influence of age on the perception of oral and/or nasal pain (irritation) has been examined in only a limited number of studies to date. In oral irritation perception, no age-related change in thresholds of capsaicin has been observed (Fukunaga et al., 2005), whereas declines with age in intranasal irritation sensitivity at supra-threshold levels were reported (Stevens et al., 1982; Stevens & Cain, 1986; Hummel et al., 1998; Frasnelli & Hummel 2003). In addition, the elderly were found to perform poorer in the discrimination of different irritants than the young (Laska, 2001). Age-related losses in intranasal trigeminal function were confirmed by studies measuring chemosensory event-related potentials (CSERP's) or negative mucosa potentials (NMP), where elderly were found to have smaller amplitudes (Hummel et al., 1998; Frasnelli & Hummel, 2003).

## Age-related changes in food liking

Until recently it was widely assumed that age-related impairment in chemosensory acuity would inevitably lead to changes in food liking with increasing age and this would lead to modifications of elderly food choice and dietary behaviour (see the critical review by Mattes, 2002). This sequence of assumptions was based on the observation that sensory acuity diminishes with age (see above) and on several reports that elderly subjects expressed on average a preference either for higher stimuli concentrations in solutions or for stronger tasting/flavoured products (Pangborn et al., 1983; Murphy & Withee, 1986; Chauhan & Hawrysh, 1988; Zallen et al., 1990; Schiffman & Warwick, 1993; De Graaf et al., 1994; De Graaf et al., 1996; De Jong et al., 1996; Griep et al., 1997; Zandstra & de Graaf, 1998; Griep et al., 2000). However, in all these studies the relationship between impaired sensory acuity with increasing age and higher optimal preferred stimuli concentrations was demonstrated at a group level and not at an individual level. Moreover, impaired sensory acuity with increasing age was assumed, although the actual sensory acuity of the subjects was measured in none of these earlier studies.

Furthermore ambiguous results were obtained in studies in which preference was assessed both in aqueous solutions and in products. On the one hand, elderly were reported to have age-related differences in preference both in solutions and "real-life" products (Murphy & Withee, 1986; Drewnowski et al., 1996). On the other hand, although the elderly still seemed to prefer higher stimuli concentrations in solutions, they were found to express preferences in "real-life" food products very similar to the young (Chauhan & Hawrysh, 1988; Chauhan, 1989; De Graaf et al., 1994; Mojet et al., 2005b). A possible explanation for this latter observation could be that food liking in humans is learned and that as people grow older, they learn to associate the foods they like with different sensory signals. Thus, the elderly might be able to compensate for sensory losses with the help of earlier acquired product concepts and consequently might not require sensory product adjustments to maintain their food liking.
Interestingly, in recent HealthSense studies, no correlation was found between sensory acuity and hedonic responses, neither at a group level nor at an individual level (Koskinen et al., 2003b; Issanchou, 2004; Forde & Delahunty, 2004). Thus, at present, the sequence of assumptions that age-related impairment in chemosensory acuity inevitably leads to changes in food liking with increasing age and that this impairment leads to modifications of elderly food choice and dietary behaviour lacks sufficient support.

## The HealthSense Project

The studies described in this thesis were part of the "HealthSense" project (Healthy Ageing: How Changes in Sensory Physiology, Sensory Psychology and Sociocognitve Factors Influence Food Choice) and were carried out with financial support from the EU, Fifth Framework Programme 1998-2002 (QLK1-CT-1999-00010). The overall objective of HealthSense was to bring together Nutritionists, Food Technologists, Food Chemists, Sensory Scientists, Psychologists and Statisticians to provide Voice-of-the-Older-Consumer information which enables policy makers, R & D and consumer groups who support the elderly to provide foods appreciated by older people. HealthSense was comprised of eight workpackages, each concentrating on different aspects of healthy ageing. The studies presented in this thesis were part of workpackage 5. The overall objective of workpackage 5 was to gain insight into the interaction and compensation mechanisms between the senses in the perception and appreciation of foods by the elderly.

## Aim and outline of this thesis

The aim of the research described in this thesis was to explore food perception and food liking with age. In sensory and nutrition research, age-associated losses in sensory function are believed to change the perception of food and to decrease food liking of the elderly, although data in support of this line of assumptions are currently scarce.

In Chapter 2 it is investigated whether or not age-related differences exist in the perception of texture (potato starch), flavour (mushroom), solvent (water/milk) and their interactions in soup. The relative importance of texture, flavour and solvent in food liking is compared on an individual level for the young and the elderly subjects.

Differences between the young and the elderly in the perception of texture (potato starch), flavour (vanilla/cheese), fat (maize oil) and their interaction in traditional sweet waffles and novel savoury waffles are explored in Chapter 3. Texture sensitivity is measured in both age groups and olfactory sensitivity is determined for the elderly subjects only. The effect of texture and olfactory sensitivity on food perception is investigated within the elderly age group. The relative importance of texture, flavour and fat in liking of the sweet and savoury waffles is compared on an individual level for the young and the elderly subjects.

Whether or not elderly and young differ in their food liking and whether or not compensatory strategies are beneficial in increasing food liking of the elderly is investigated in Chapter 4. Liking is assessed in one well known (custard desserts) and one novel (tomato-spirulina health drink) food. Several compensatory strategies are incorporated into these foods: flavour enhancement/enrichment, textural change, and/or irritant addition. The influence of age on the relative importance of texture, flavour and/or irritation is also studied. An olfactory sensitivity test is included to investigate whether or not impairment in olfactory sensitivity is associated with food liking.

In Chapter 5 it is investigated whether or not the elderly require a larger stimulus increase in order to experience a difference than the young. In this experiment the flavour (cherry), thickener (whey protein concentrate) and irritant (capsaicin) concentrations are determined for the study presented in the following chapter.

Chapter 6 investigates all the aspects of the "sequence of assumptions" that age-associated losses in sensory function change the food perception of the elderly and decrease their food liking. Intensity and liking ratings for the same elderly and young are assessed in a food system (custard dessert), in which compensatory strategies were incorporated: flavour enrichment, textural change and irritant addition. Different sensory acuity tests are included (taste, olfaction, irritation, mastication). In addition, the influence of demographic factors, food habits or oral health on perception and liking of the elderly is studied.

An overview of the experiments is shown in Figure 6.

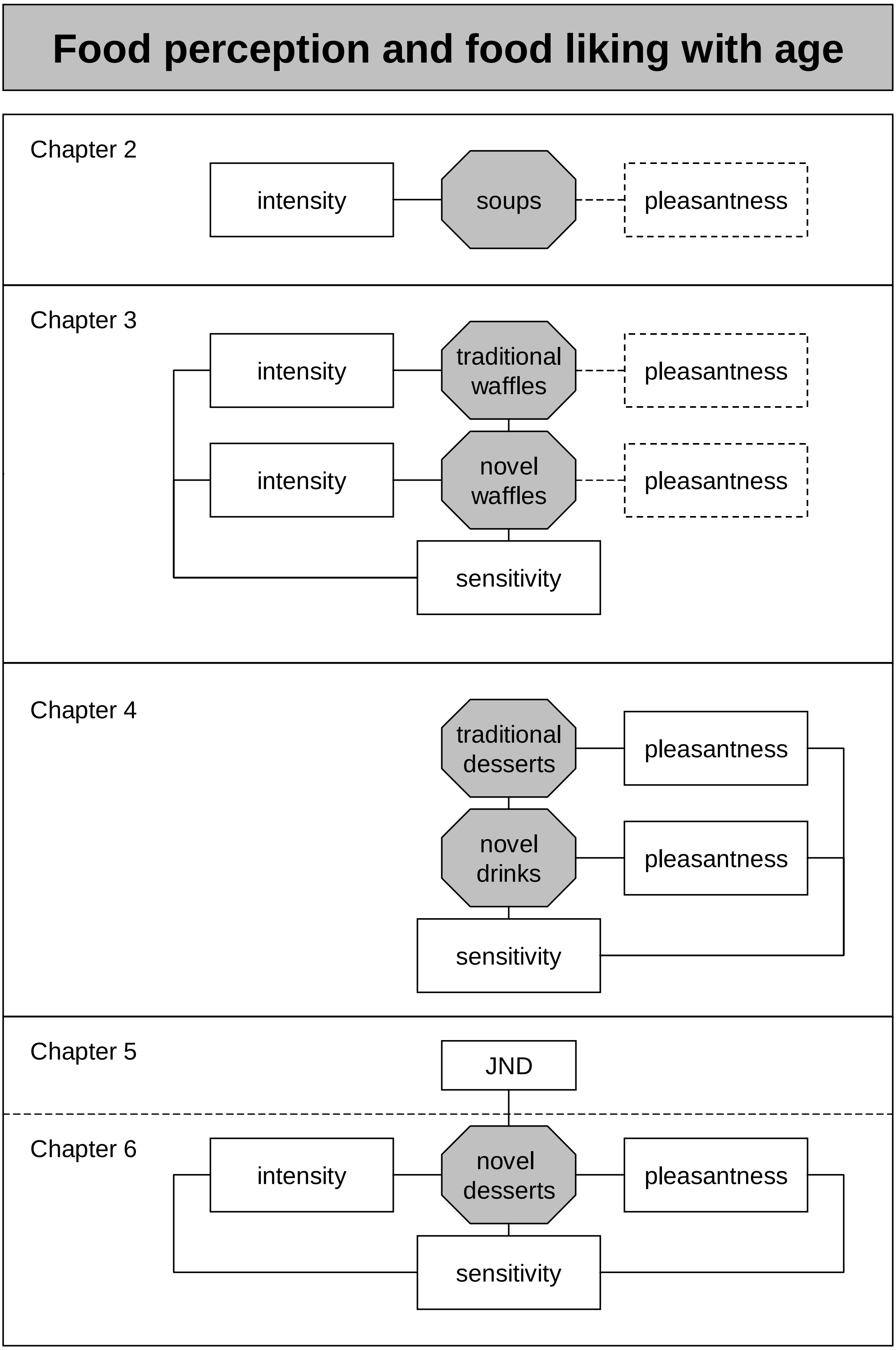


*Figure 6. Outline of the experiments in the present thesis.*

# Chapter 2

## Perception of texture and flavor in soups by elderly and young subjects

Stefanie Kremer, Jos Mojet and Jan H.A. Kroeze

Journal of Texture Studies 36: 255–272, 2005

## Abstract

The perception of texture and flavor and their interaction effects in white cream soups were studied in 12 young subjects (18–29 years) and 15 elderly subjects (60–84 years). Eight soup samples (2 x 2 x 2 factorial design) were prepared with or without potato starch, with or without mushroom flavor and with water or with milk. The elderly were less sensitive to changes in the flavor profile of the soups than the young, and their perception of creaminess was reduced. Solvent by flavor interaction effects were independent of age, whereas texture by flavor interaction effects were age specific. Besides the intensities of flavor and texture attributes, pleasantness was also assessed. No indication was found that the contribution of texture and flavor to food appreciation was different for the young and for the elderly in the current study. This study supports the assumption that age-related differences in product perception exist.


## Introduction

The human aging process is generally accompanied by a decrease in sensory functioning because sensory receptors age, and their neural efficiency drops (Corso, 1981). The existence of losses in the sensory acuity of taste and smell with increasing age is widely acknowledged (Murphy, 1993; Stevens & Cain, 1993; De Graaf et al., 1994; Mojet et al., 2001, 2003). However, these changes are not uniform. The sense of smell is described to be more prone to losses than the sense of taste (Stevens et al., 1984).

Texture perception is a complex process involving the sensory modalities of vision, hearing, somesthesis and kinesthesis (Christensen, 1984). Ageassociated factors, e.g., poor oral health, reduced chewing efficiency or intake of medications, are thought to influence the oral processing of food (Ship et al., 1996). Furthermore, Szczesniak (1990) suggested that once the flavor perception is diminished, the texture attributes could become more important in food perception and appreciation.

In food perception, complex interactions among the inputs from different sensory modalities might take place (Stein and Meredith, 1990). Different change rates in the age-related decline in sensitivity to smell, taste and/or texture lead to changes in the integrated product perception. A fair amount of research has been conducted on texture–flavor interactions. It has been shown that the perceived taste intensity is reduced as the viscosity of solutions and gels is increased (Moskowitz & Arabie, 1970; Christensen, 1980; Calvino et al., 1993; Smith & Noble, 1998; Hollowood et al., 2002), and an increase in the hydrocolloid concentration reduced the perceived flavor intensity (Pangborn et al., 1978; Baines & Morris, 1989). None of these studies investigated whether age-related losses in sensitivity influenced the interaction between these factors.

Studies on the relationship between age and food appreciation in products have led to mixed results. Even though Little & Brinner (1984) reported a slight but significant decline in salt perception in tomato juice with age, the elderly did not show a change in preference. Instead, they preferred those samples that were also most preferred by the young subjects. In addition, no age-related difference was found for the pleasantness of salt in chicken (Chauhan, 1989) or tomato soup (Mojet et al., 2005). On the other hand, Drewnowski et al. (1996) found that the elderly prefer even less salty soups than the young, whereas de Graaf et al. (1996) reported that the elderly had higher optimal-preferred flavor concentrations in bouillon, tomato soup, chocolate custard and orange-flavored drink.

Recent studies have reported age-related differences in the impact of texture on pleasantness. In muesli and soup, texture attributes were shown to have a higher impact on the pleasantness ratings of the elderly than those of the young (Forde & Delahunty, 2002; Kälviäinen et al., 2002). In a later study, texture was found to be less important for yogurt pleasantness ratings given by the elderly compared to the young (Kälviäinen et al., 2003).

So far, the majority of studies on texture–flavor interactions has used either water-thickener solutions or gels as a model food system. Because the relevance of the intensity measurements in these model systems may have little predictive value for real-life perception of complex foods (De Graaf et al., 1994; Mojet et al., 2003), white cream soups were used in the present study to simulate a "real life" product. Throughout the article, the term flavor is used for the combined retro-nasal odor and taste perception.

The aim of this study was to investigate the differences in texture and flavor perception and their interaction effects in young and elderly subjects. Furthermore, it was studied whether age-related differences in the contribution of texture and flavor to food appreciation could be observed. Because the size of the age groups in this study is small, the results on the texture and flavor contribution to food appreciation should serve as an indication only and cannot be generalized to the population at large.

# Materials and Methods

### Stimuli

Commercially available powdered, chicken-flavored white cream soup (Unilever-Bestfoods, Vlaardingen, the Netherlands) was used as the basis for the liquid food system. Three factors were included according to a 2 x 2 x 2 full factorial design: 2 texture conditions, with and without potato starch (AVEBE Corp., Veendam, the Netherlands); 2 flavor conditions, with andwithout mushroom flavor (IFF B.V., Hilversum, the Netherlands) and 2 solvent conditions with water or with milk (3.5% fat). The preparation of white cream soup with milk instead of water is recommended by the manufacturer and is quite common in the Netherlands. Table 1 shows the ingredient composition of the eight soup samples.

The soups were prepared 1 h before the tasting sessions and were kept at 60C in a water bath (au bain-marie) until serving. Twenty-milliliter portions of the soups were served in 100-mL polystyrene soup bowls with plastic tablespoons.

### Subjects

Forty elderly and 40 young subjects were recruited by advertisements in local newspapers. They had to meet the following criteria: healthy, not on a therapeutic diet, community dwelling, not pregnant or lactating and not subject to food allergies. Furthermore, the potential panelists had to pass a screening test procedure that prevented participation in the panel of young or elderly subjects suffering from anosmia (insensitive to all

*Table 1. Composition of the soup samples per 70-g basic soup powder dissolved in water to a volume of 1000 mL.*

| Product | Texture<br>Potato starch (g) | Flavor<br>Mushroom flavor (g) | Solvent<br>Milk (mL) |
|---|---|---|---|
| Soup 1 | – | – | – |
| Soup 2 | – | – | 900 |
| Soup 3 | – | 1.5 | – |
| Soup 4 | – | 1.5 | 900 |
| Soup 5 | 6 | – | – |
| Soup 6 | 6 | – | 900 |
| Soup 7 | 6 | 1.5 | – |
| Soup 8 | 6 | 1.5 | 900 |

odors or to a specific odor[s]) or ageusia (insensitive to all tastes or to a specific taste quality). The Dutch odor identification test, Geur Identificatie Test Utrecht (GITU), was used to test for anosmia (Hendriks, 1988). Thirty-six selected odorants had to be smelled and identified. For each correct response out of four possible answers, one point was given. Subjects with a score of 19 or below (anosmics or severe hyposmics) were not admitted to the panel.

A modified version of the four-basic taste test was used to test for ageusia (Van Gemert, 1985). The subjects first received five cups with the following solutions: sweet (10-g saccharose/L), sour (0.8-g citric acid/L), salty (2-g sodium chloride/L), bitter (1-g caffeine/L) and neutral (tap water). They had 5 min to learn these tastes. Next, they received each taste twice in another 10 cups that were coded with three-digit numbers. Subjects with more than two incorrect responses for all tastes or with two incorrect responses for the same basic taste were not admitted to the panel.

After screening and checking for their availability on the days of testing, the young panel consisted of 15 subjects and the elderly panel consisted of 17 panelists.

During the first training sessions, three young and two elderly subjects refrained from further participation because of other obligations. The final panel of young adults consisted of 12 subjects (age range 18–29 [23 ± 3.4]), all norgeusmics (with normal taste) and normosmics (with normal smell). The final panel of elderly consisted of 15 subjects (age range 60–84 [68 ± 7.3]), all norgeusmics, 9 normosmics and 6 slight or medium hyposmics (with a GITU score between 21 and 29). The subjects were paid for their participation at the completion of the test.

### Procedure

Before the experiment, all subjects underwent three 2-h training sessions in which they were familiarized with the task, product type, chosen attributes and correct use of the rating scales. During this short training period, the panelists received different soup samples but never the particular samples that were assessed later in the actual experiment. The experiment was conducted during three identical sessions of approximately 90 min. In each of these sessions, all eight soups were assessed. The soup samples were all coded with random three-digit numbers and were presented in random order per person and per session. The same randomization was applied for the two age groups. Between samples, a piece of cracker and water were used to neutralize the taste and to rinse the palate. The basic soup was always presented at the start of a session as a dummy product to prevent the occurrence of first-order effects. The ratings for this dummy product were excluded from the data analysis afterwards. The same basic soup was also included in the randomised presentation.

For all samples, the pleasantness was rated first on a 100-mm visual analog scale and subsequently, the intensities of the sensory attributes of thickness, creaminess, flouriness, roughness, stickiness, swallowing effort, taste intensity, mushroom flavor, saltiness and chicken flavor were rated on a similar scale. The verbal anchors were Dutch terms that translated to "very little/weak" and "very much/strong" and were placed at 10 and 90% of the scale, respectively.

### Data Analysis

The average of the three replications was used in the analyses. For the investigation of the main effects and the interaction effects of age, flavor, texture and solvent, an univariate repeated measure analysis of variance (ANOVA) was conducted per attribute and pleasantness rating, with age as between-subjects factor and texture, flavor and solvent as within-subjects factors. The analyses of variance were performed using SPSS version 10.0 (SPSS Inc. Chicago, IL). Only results with an observed power >0.70 and a significance level of alpha ≤ 0.05 were reported in the Results section.

Traditional conjoint analysis was conducted on the pleasantness ratings of each person to estimate the relative importance of texture, flavor and solvent on the food appreciation of the individual. Conjoint analysis is a multivariate technique that explains not only the importance of each factor, which is manipulated by the experimenter for pleasantness (factor importance), but also how the levels within each factor influence these pleasantness ratings (partworth estimates). Thus, a factor level with a positive partworth estimate will have influenced the pleasantness ratings positively and vice versa (Hair et al., 1998). Because of the substantial amount of among-person variation in pleasantness ratings, conjoint analysis is usually carried out at the individual level (Green & Srinivasan, 1978). If one wants to summarize the factor importance for different groups, it is best to first compute the factor importance for the subjects individually and then to average them (Orme, 2002), as was carried out in the current study.

## Results

### Sensory Effects of the Varied Factors on the Soup Samples

The addition of the potato starch to the soups increased the perceived thickness ($F$ [1,25] = 39.96, $P < 0.01$), creaminess ($F$ [1,25] = 8.81, $P < 0.007$), flouriness ($F$ [1,25] = 18.51, $P < 0.001$), roughness ($F$ [1,25] = 15.03, $P < 0.001$), stickiness ($F$ [1,25] = 24.68, $P < 0.001$), swallowing effort ($F$ [1,25] = 23.46, $P < 0.001$) and decreased the taste intensity ($F$ [1,25] = 7.48, $P < 0.011$). Adding a mushroom flavor to the soups increased the perception of taste intensity ($F$ [1,25] = 11.92, $P < 0.002$), mushroom flavor ($F$ [1,25] = 5.59, $P < 0.026$) and saltiness ($F$ [1,25] = 6.63, $P < 0.016$). The preparation of the soups with milk instead of water increased the perception of all texture attributes: thickness ($F$ [1,25] = 47.11, $P <$ 0.001), creaminess ($F$ [1,25] = 48.33, $P < 0.001$), flouriness ($F$ [1,25] = 18.46, $P < 0.001$), roughness ($F$ [1,25] = 25.38, $P < 0.001$), stickiness ($F$ [1,25] = 25.01, $P < 0.001$) and swallowing effort ($F$ [1,25] = 41.69, $P < 0.001$).

### Age and Texture Perception

The elderly perceived the creaminess ($F$ [1,25] = 5.33, $P < 0.03$) as less intense than the young (Fig. 1). The addition of the mushroom flavor had a different effect for both the elderly and the young on the perceived thickness ($F$ [1,25] = 6.89, $P < 0.015$). The young perceived the flavored soups as significantly less thick, whereas the elderly did not perceive a difference in thickness (Table 2).

### Age and Flavor Perception

The elderly perceived mushroom flavor ($F$ [1,25] = 22.14, $P < 0.001$) and chicken flavor ($F$ [1,25] = 12.06, $P < 0.002$) as less intense than the young (Fig. 1).
The addition of the mushroom flavor had a different effect for the elderly and the young on the perceived mushroom flavor ($F$ [1,25] = 6.18, $P < 0.020$). When the mushroom flavor was added to the soups, the young perceived an increase in mushroom flavor intensity, whereas the elderly did not (Table 2). The preparation of the soups with milk decreased the chicken flavor perception ($F$ [1,25] = 12.93, $P < 0.001$) for the young, while it had no effect on the flavor perception of the elderly (Table 3).


*Figure 1. Mean intensity ratings (±SEM) for perceived creaminess, mushroom flavor and chicken flavor by elderly and young subjects.*

*Table 2. Mean intensity ratings (+SEM) of thickness and of mushroom flavor for flavored and unflavored soups by elderly and young subjects.*

| Attribute | Subjects | Factor | Mean intensity | Standard error | Perceived intensity |
|---|---|---|---|---|---|
| Thickness | Young | No flavor | 44.03 | 1.20 | ↓ |
| | | Mushroom flavor | 41.40 | 1.37 | |
| | Elderly | No flavor | 42.36 | 1.07 | – |
| | | Mushroom flavor | 43.05 | 1.23 | |
| Mushroom flavor | Young | No flavor | 21.19 | 1.82 | ↑ |
| | | Mushroom flavor | 25.83 | 2.70 | |
| | Elderly | No flavor | 12.06 | 1.63 | – |
| | | Mushroom flavor | 11.99 | 2.41 | |

↓, decrease in perceived intensity; ↑, increase in perceived intensity; –, no change.

*Table 3. Mean intensity ratings (+SEM) of chicken flavor for soups prepared with water or with milk for elderly and young subjects.*

| Attribute | Subjects | Factor | Mean intensity | Standard error | Perceived intensity |
|---|---|---|---|---|---|
| Chicken flavor | Young | Water | 20.10 | 1.85 | ↓ |
| | | Milk | 15.29 | 1.28 | |
| | Elderly | Water | 10.61 | 1.66 | – |
| | | Milk | 11.16 | 1.14 | |

↓, decrease in perceived intensity; ↑, increase in perceived intensity; –, no change.

## *Age and the Perception of Texture by Flavor Interactions*

Table 4 shows the age by texture by flavor interactions found for perceived thickness ($F$ [1,25] = 9.29, $P < 0.005$) and for mushroom flavor ($F$ [1,25] = 13.65, $P < 0.001$). For both mushroom flavored and unflavored soups, the young perceived an increase in thickness when the soups were thickened with potato starch. In contrast, the elderly only perceived an increase in thickness for the unflavored soups. The young perceived an increase in mushroom flavor when the thickener was added to the flavored soups and a decrease when it was added to the unflavored soups. The elderly did not perceive any difference in mushroom flavor intensity.

*Table 4. Mean intensity ratings (+SEM) for perceived thickness and for mushroom flavor for flavored and unflavored soups prepared with water or with milk for elderly and young subjects.*

| Attribute | Subjects | Factor I | Factor II intensity | Mean error | Standard intensity | Perceived |
|---|---|---|---|---|---|---|
| Thickness | Young | No thickener | No flavor | 42.03 | 1.71 | – |
| | | | Mushroom flavor | 39.36 | 1.55 | |
| | | Thickener | No flavor | 46.03 | 1.38 | – |
| | | | Mushroom flavor | 43.43 | 1.51 | |
| | Elderly | No thickener | No flavor | 38.24 | 1.53 | ↑ |
| | | | Mushroom flavor | 42.46 | 1.38 | |
| | | Thickener | No flavor | 46.48 | 1.24 | – |
| | | | Mushroom flavor | 43.64 | 1.35 | |
| Mushroom flavor | Young | No thickener | No flavor | 22.56 | 1.91 | – |
| | | | Mushroom flavor | 24.86 | 2.63 | |
| | | Thickener | No flavor | 19.82 | 1.84 | ↑ |
| | | | Mushroom flavor | 26.79 | 2.83 | |
| | Elderly | No thickener | No flavor | 11.96 | 1.71 | – |
| | | | Mushroom flavor | 12.39 | 2.35 | |
| | | Thickener | No flavor | 12.17 | 1.65 | – |
| | | | Mushroom flavor | 11.59 | 2.53 | |

↓, decrease in perceived intensity; ↑, increase in perceived intensity; –, no change.

Solvent by flavor interactions were found to play a role in the perception of thickness ($F$ [1,25] = 11.99, $P$ < 0.002), creaminess ($F$ [1,25] = 7.98, $P$ < 0.009) and roughness ($F$ [1,25] = 10.19, $P$ < 0.004). In contrast to the unflavored soups, adding a mushroom flavor to water-based soups decreased the perceived intensity of these texture attributes, whereas adding the same flavor to soups prepared with milk increased intensity perception. No agerelated difference was found in the perception of the solvent by flavor interactions. A complex three-way interaction was found for perceived stickiness ($F$ [1,25] = 9.51, $P$ < 0.005). In soups without the thickener added, adding a mushroom flavor to water-based soups decreased the perceived stickiness, whereas by adding the same flavor to soups prepared with milk an increase of perceived stickiness was found. In soups with the thickener added, adding a mushroom flavor to the soups decreased the stickiness perception for soups prepared with water as well as for those prepared with milk.

### *Pleasantness Ratings*

No overall age effect on the pleasantness ratings was found. The relative factor importance of texture, flavor and solvent on the pleasantness ratings of each subject is shown in Table 5.

Most elderly and young subjects demonstrated a tendency to prefer soups prepared with water and with no extra addition of starch. No clear tendency could be observed with respect to the flavor manipulation. Finally, looking at the groups' means, no indications for age-related differences in the contribution of texture and flavor to food appreciation can be reported for the two age groups of the present study.

## Discussion

The results of this study on age-related differences in the perception of texture and flavor and their interaction effects indicate the following: First, age-related differences exist in texture perception. Secondly, age has a diminishing effect on flavor perception, and the elderly are less sensitive to changes in the flavor profile. Thirdly, age-related differences exist in the perception of texture–flavor interactions. Finally, the importance of flavor, texture and solvent on pleasantness appears to be similar for the young and the elderly in this study.

Two difficulties arise when the present results are compared with the findings in the literature. The first difficulty lies in the extent to which the results can be generalized, because different studies used different food systems. Thus, a difference in outcome can be due to differences in the products used. The second difficulty is related to the criteria for the selection of subjects used in the different studies such as age range, health status, mobility, etc. For example, in the present study, the young and the elderly were accepted into the panel only after they passed a screening test procedure. It is important to point out that this screening test procedure only prevented the participation of people with an abnormality in taste/smell perception and not the participation of people with an age-related impairment in taste/smell perception. This selection criterion is not adopted by most other studies and thus, a direct comparison of the results of the present study with these studies should be performed with caution. Because of practical reasons, two age groups were used to investigate the age-related differences in perception and pleasantness instead of using a longitudinal study setup in which the same subjects are studied over a longer period of time. Therefore, it cannot be completely ruled out that the conclusions on the effect of age might be biased by a cohort effect.

*Table 5. Traditional conjoint analysis: The factor importance (%) of flavor, texture and solvent on pleasantness per subject and per age group.*

| | | | | | | | | | | | | | | | | | Mean | Frequency | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | | | | + | 0 | - |
| Young subject no. | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | x | x | x | | | | |
| Texture | | 15.0% | 10.0% | 11.5% | 20.0% | 12.5% | 0.0% | 10.0% | 12.5% | 0.0% | 0.0% | 21.4% | 7.6% | | | | 10.0% | | | |
| Starch | none | + | + | – | + | + | 0 | – | + | 0 | 0 | + | – | | | | | 6 | 3 | 3 |
| | added | – | – | + | – | – | 0 | + | – | 0 | 0 | – | + | | | | | 3 | 3 | 6 |
| Flavor | | 80.0% | 10.0% | 27.0% | 20.0% | 0.0% | 66.7% | 10.0% | 25.0% | 11.1% | 88.9% | 57.2% | 46.2% | | | | 36.8% | | | |
| Mushroom | none | + | + | – | + | 0 | + | – | – | – | + | + | – | | | | | 6 | 1 | 5 |
| | added | – | – | + | – | 0 | – | + | + | + | – | – | + | | | | | 5 | 1 | 6 |
| Solvent | | 5.0% | 80.0% | 61.5% | 60.0% | 87.5% | 33.3% | 80.0% | 62.5% | 88.9% | 11.1% | 21.4% | 46.2% | | | | 53.2% | | | |
| | water | – | + | – | + | + | – | + | + | + | – | + | + | | | | | 8 | 0 | 4 |
| | milk | + | – | + | – | – | + | – | – | – | + | – | – | | | | | 4 | 0 | 8 |
| Elderly subject no. | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | | | | |
| Texture | | 38.5% | 10.0% | 26.7% | 11.1% | 13.0% | 5.9% | 23.1% | 38.5% | 0.0% | 0.0% | 6.7% | 10.5% | 8.3% | 8.3% | 18.2% | 14.6% | | | |
| Starch | none | + | – | + | – | + | + | + | + | 0 | 0 | + | + | – | – | + | | 9 | 2 | 4 |
| | added | – | + | – | + | – | – | – | – | 0 | 0 | – | – | + | + | – | | 4 | 2 | 9 |
| Flavor | | 38.5% | 10.0% | 40.0% | 0.0% | 17.4% | 94.1% | 15.4% | 7.7% | 11.1% | 11.1% | 86.6% | 5.3% | 25.0% | 66.7% | 9.1% | 29.2% | | | |
| Mushroom | none | – | – | + | 0 | + | + | + | + | + | – | + | – | – | + | – | | 8 | 1 | 6 |
| | added | + | + | – | 0 | – | – | – | – | – | + | – | + | + | – | + | | 6 | 1 | 8 |
| Solvent | | 23.0% | 80.0% | 33.3% | 88.9% | 69.6% | 0.0% | 61.5% | 53.8% | 88.9% | 88.9% | 6.7% | 84.2% | 66.7% | 25.0% | 72.7% | 56.2% | | | |
| | water | + | – | + | – | + | 0 | + | + | + | – | – | – | + | + | + | | 9 | 1 | 5 |
| | milk | – | + | – | + | – | 0 | – | – | – | + | + | + | – | – | – | | 5 | 1 | 9 |

+, indicates a positive part-worth estimate; –, a negative part-worth estimate; 0, indicates no contribution.

## *Age and the Perception of Texture*

The two age groups differed in the perception of texture. The elderly perceived the soups as less creamy than the young. Different explanations for this finding are possible. Creaminess is described to have resulted from a combination of flavor/taste, mouthfeel and after-feel sensations (De Wijk et al., 2003; Weenen et al., 2005), and the elderly are frequently reported to suffer from impairments in the perception of odors and flavors (Stevens et al., 1984; Stevens & Cain, 1987; Cain et al., 1990). In the present study, the creaminess impression may be lowered just because the elderly perceived the flavor sensations of creaminess to a lesser degree. Similarly, changes in oral health and/or oral processing with age may cause differences in the intraoral perception of creaminess-related mouthfeel sensations, which in turn will also lead to a decreased creaminess perception. Alternatively, a cohort effect may have played a role. The elderly grew up with higher fat levels in food and may therefore have a higher internal reference for creaminess than the young who are much more familiarized with low fat products (Löwik et al., 1998).

The soups with added mushroom flavor were perceived to be less thick only by the young. Whether this is because the elderly did not perceive the mushroom flavor or because the young paid more attention to flavor cues remains to be investigated further.

## *Age and the Perception of Taste and Flavor*

The two age groups differed in the perception of the flavor but not of the taste attributes. The elderly rated both the mushroom flavor and the chicken flavor intensities in the white cream soups as less intense than the young. No significant age-related differences were found in the perceived overall taste intensity and saltiness. These findings are consistent with the work of Stevens et al. (1984), who demonstrated that age-related losses of suprathreshold intensity occur more commonly in the sense of smell than in the sense of taste. Notwithstanding the differences in food systems used by the different authors, the following observation can be made: The majority of authors that investigated the perception of salt dissolved in "real life" products have demonstrated that there is no age-associated deficit in saltiness (Stevens & Lawless, 1981; Warwick & Schiffman, 1990; Zallen et al., 1990; Drewnowski et al., 1996). At first sight, the results of the present study disagree with the recent findings of Mojet et al. (2003), who identified an age effect in the suprathreshold perception of salty tastants in tomato soup. However, besides the differences between the products used, the age effect reported by Mojet et al. (2003) was mainly caused by elderly men, and in the present study, more elderly women participated than men.

The mushroom flavor was neither perceived nor recognized by the elderly. Both the detection and the identification of odors have been shown to be impaired with age (Schemper et al., 1981; Doty et al., 1984; Cain et al., 1990; Lehrner et al., 1999; Larsson et al., 2000), suggesting that the mushroom flavor concentration added to the soups may have been too low for the elderly to be either perceived or recognized.

Only the young perceived less chicken flavor in the soups that were prepared with milk instead of water. The addition of milk mainly increases the fat content but also adds some extra proteins and, to a lesser extent, carbohydrates to the soups. Fat is known to influence the temporal profile, the flavor impact, the perception of flavor notes and the order of their occurrence (Hatchwell, 1996; de Roos, 1997). Carbohydrates can change the volatility of flavor compounds (Godshall, 1997), and proteins are known to influence the flavor release through physical or chemical reactions with the flavor components (Fischer & Widder, 1997). It seems possible that the addition of milk has led to changes in the flavor profile of the soups in such a way that it reduced the intensity of chicken flavor for the young. A change in the flavor profile did not occur for the elderly.

### *Age and the Perception of Interaction Effects*

To our knowledge, solvent–flavor or texture–flavor interaction effects have not been studied in the elderly before. A limited number of studies have investigated age-related odor–taste interaction effects (Hornung & Enns, 1984; Enns & Hornung, 1985) and found no interaction effect to be related to age. In the present study, no age-related differences in solvent–flavor interactions were observed, whereas the texture–flavor interaction effects for thickness and for mushroom flavor were found to be different for the elderly and the young.

The elderly perceived an increase in thickness when the flavor was added to the soups without a thickener. In contrast, the young did not perceive any difference in thickness. This would mean that even though the elderly did not perceive the flavor addition, it still affected their thickness perception – but only in the very specific case where no thickener was added to the soups.

In a study by Pangborn & Szczesniak (1974), the addition of flavor was reported to reduce the perceived viscosity of water-thickener solutions. In the present study, the opposite occurred for the elderly. Texture–flavor interactions have been reported to be product and stimulus specific (Pangborn et al., 1978; Christensen, 1980), which might explain the discrepancy in these findings.

Only the young perceived an increase in mushroom flavor when it was added to the thickened soups. Seemingly, even the young had difficulties in the perception of the mushroom

flavor when no thickener was added to the soups. Hydrocolloids are generally thought to either decrease flavor perception with much of the effect being attributed to viscosity and to hindered diffusion (Pangborn et al., 1973) or at least to remain relatively stable below the coil overlap parameter c* (Baines & Morris, 1989). In the present study, the opposite occurred. Both of the observed age-related interaction effects seemed not only to be product-type specific but also highly stimulus specific. For this reason, the authors feel that any further attempt to explain these findings would be highly speculative.
According to Koskinen et al. (2003), the elderly differ in their world of sensations from the young to such an extent that they experience a different product. The present findings are supportive of this assumption. Whether these age-related differences in the perception and integration of sensations will have practical implications for the development of special food products for the elderly needs further investigation.

### *Contribution of Flavor, Texture and Solvent to the Pleasantness Ratings*

The elderly and the young of the present study exhibit no clear difference in the importance of the influence of the texture, flavor and solvent factors on their pleasantness ratings.
In vegetable soup, texture attributes became influential in the pleasantness ratings of the elderly (Forde and Delahunty, 2002). Similarly, experimental texture manipulations in muesli were shown to have a higher impact on the pleasantness ratings of the elderly than of the young (Kälviäinen et al., 2002). The notion by Szczesniak (1990) that diminishing flavor perception results in an increased influence of texture attributes on food perception and pleasantness is supported by both of these two studies. In contrast, in a study on yogurt, texture was found to be less important for the pleasantness ratings of the elderly, and they were more willing to accept a variety of textural modifications in foods (Kälviäinen et al., 2003). The observations of the current study are not in line with any of these findings. It is difficult to compare these results, because different food systems were used.
It is widely assumed that sensory changes associated with aging translate into modifications of food pleasantness and food choice, but data in support of this assumption are currently lacking (Mattes, 2002), and the results of the present study are also not supportive of this assumption. Although there were differences in the perception of flavor and texture by the two age groups, no difference in the relative factor importance was observed, and the young and elderly subjects demonstrated similar tendencies in the influence of the factor levels on their pleasantness ratings. These results are in accordance with the following observations that were made in related fields of research: losses

in sensory input did not have a negative effect on elderly food intake (Ferris & Duffy, 1989; Mattes et al., 1990), and elderly people, even when they lose some sensory capabilities, demonstrated a remarkable stability in their food pleasantness (Mojet et al., 2005).

In conclusion, the results support the assumption that age-related differences in product perception exist. No indication was found that the contribution of texture and flavor to food appreciation was different for the young and the elderly in the current study.

## Acknowledgments

This work is a part of the "HealthSense" project (Healthy Aging: How Changes in Sensory Physiology, Sensory Psychology and Sociocognitve Factors Influence Food Choice) and was carried out with financial support from the European Union, Fifth Framework Programme 1998–2002 (QLK1-CT-1999-00010). Special thanks to Ilse Polet, Rudi van Doorn and Monique Theunis for their assistance in conducting the study and to Rene de Wijk and Jon Prinz for their useful comments on the manuscript.

# Chapter 3

# Differences in perception of sweet and savoury waffles between elderly and young subjects

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Food Quality and Preference, 2006, in press

## Abstract

Differences between two age groups in texture and flavour perception, in food appreciation and in texture and olfactory sensitivity were investigated. Three experiments were conducted: ratings of texture and flavour attributes, ratings of pleasantness of (1) sweet vanilla waffles, (2) savoury cheese waffles by elderly (n = 22, 60–85 years) and young (n = 16, 18–35 years) subjects, and (3) tests measuring texture sensitivity (young and elderly) and olfactory sensitivity (elderly only). The elderly differed from the young in their perception of texture and flavour, but the observed texture flavour interaction effect was not different for the elderly and young. A decrease in the importance of flavour in food appreciation was observed for the elderly in the savoury but not in the sweet waffles. The young were more efficient in chewing and they were better in oral letter recognition test. Among the elderly, olfactory sensitivity influenced flavour intensity ratings, whereas poor texture sensitivity was not related to perception of sensory attributes.

The present study does not support the hypothesis that a different rate in the decline of the different senses with age will inevitably lead to a different integrated product concept.


## Introduction

The impairment of the sense of smell with increasing age has been described by a number of authors. The elderly perceived odours as less intense (De Graaf et al., 1994; Murphy, 1983; Stevens et al., 1984; Stevens & Cain, 1987) and they also experienced greater difficulties in odour identification and discrimination (De Wijk & Cain, 1994; Lehrner et al., 1999; Thomas-Danguin et al., 2003).

Contradicting findings have been reported on the change in perception of taste with age. About half of the reported studies showed a diminished sensitivity with increasing age for specific taste qualities when the tastants were dissolved in water (for a review, see Mojet et al., 2003). However, when similar tastants were dissolved in food: no or little age effect was found in the majority of studies (De Graaf et al., 1994; Drewnowski et al., 1996; Little & Brinner, 1984; Mojet et al., 2003; Stevens & Lawless, 1981; Warwick & Schiffman, 1990; Zallen et al., 1990).

Little is known about the effect of age on oral texture perception. Ageing modifies various aspects of oral physiology such as dental status, bite force, composition of saliva or muscle fatigue (for a review, see Ship, 1999), that makes it reasonable to expect at least an indirect influence of age on texture perception. Among those aspects, dental status and oral health are thought to have the highest impact since dental integrity is the prime regulator of masticatory performance (Wayler et al., 1984). Elderly, especially those with partial or complete dentures, are reported to have impaired masticatory efficiency (Heath, 1982). However, healthy elderly have been shown to easily compensate for any reduced masticatory efficiency by changing their chewing behaviour for example, by increasing the number of chews or by increasing the chewing duration (Mioche, 2004). Other oral sensations, such as vibratory and thermal sensitivity, were found to remain relatively stable with aging, and were only slightly lower in people over 80 years of age (Calhoun et al., 1992). Thus, it remains to be further investigated whether or not differences in texture sensitivity and/or in the perception of texture in foods vary with age.

Although aging is accompanied by decreased efficiency in perceptual processing in general, this decrease may not be uniform in all senses. For example, studies on the relative impact of age on taste and smell have indicated that aging affects smell stronger than taste (Stevens et al., 1984). Furthermore, more variability in perceptual capabilities occurs among elderly than among young people. While some elderly have impaired sensory acuity, others have identical acuity to those of younger people (Calhoun et al., 1992; Heath, 1982; Koskinen et al., 2003; Thomas-Danguin et al., 2003).

While eating or drinking, individuals experience a number of sensations, which are integrated into one product concept or ''gestalt''. Since not all senses decline at the same rate with increasing age, it may be expected that the interaction of the senses contributing to this gestalt may differ between the elderly and the young. Only a few authors have investigated age-related interaction effects so far. In two studies on orthonasal smell–taste interactions, no age-related effect was reported (Hornung & Enns, 1984; Enns & Hornung, 1988). In a recent study on texture–flavour interactions in white cream soup, elderly and young subjects differed in their integrated concepts (Kremer et al., 2005).

Changes in sensory acuity with age could have an influence on the food appreciation of elderly people. However, data in support of this notion are currently lacking (Mattes, 2002).Texture manipulations in muesli were shown to have a higher impact on pleasantness of the elderly than of the young (Kälviäinen et al., 2002). Similarly, texture attributes had more influence on pleasantness ratings of elderly than young people (Forde & Delahunty, 2002). For yoghurt, the texture contribution to pleasantness was lower for elderly than young people (Kälviäinen et al., 2003). However, in white cream soups the relative importance of texture and flavour to appreciation was similar in the young and the elderly (Kremer et al., 2005). Thus, the attention shift in food appreciation from one dominant factor to another may be product dependent.

The present study consists of three experiments, of which the first two explore differences between two age groups in the perception of texture, flavour and their interaction in sweet waffles (Experiment 1) and savoury waffles (Experiment 2). The hypothesis was that elderly and young demonstrate differences in the mentioned product perceptions. In both experiments, it was also studied whether age-related differences in the relative importance of the factors texture, flavour and fat in food appreciation could be observed. It was anticipated that the relative contribution of flavour to food appreciation was lower for the elderly compared to the young. Sweet waffles are a well-known product to Dutch consumers, whereas savoury waffles, which are unavailable on the Dutch market, are quite novel to them. The occurrence of age-related effects on perception and food appreciation is likely to be influenced by prior product experience, i.e., the elderly may be able to compensate for sensory losses with the help of earlier acquired product concepts. In the third experiment, texture sensitivity was measured in both age groups and olfactory sensitivity was determined for the elderly subjects only. The aim of the third experiment was to investigate possible age differences in texture sensitivity, and to examine within the elderly age group the effect of texture and olfactory sensitivity on food perception. It was hypothesised that poor flavour and/or texture sensitivity leads to a decreased perception of the complex food systems used in this study. Throughout the paper the term flavour is used for the combined perception of retro-nasal odour and taste.

## Materials and methods

### *Subjects*

Twenty-five elderly and twenty-five young subjects were recruited by means of advertisements in local newspapers. They had to meet the following criteria: healthy, not on a pre-described diet, community dwelling, not pregnant or lactating, and not having any food allergy. A taste or smell abnormality was used as an exclusion criterion for acceptance into the panel. To this aim, the Dutch odour identification test (Hendriks, 1988) was used to test for anosmia [insensitive to all odours or to specific odour(s)]. Thirty-six selected odorants had to be smelled and identified. For each correct response, out of four possible responses, one point was given. Subjects with a score of 19 or below (anosmics or severe hyposmics) were not admitted to the panel. A slightly modified version of the four-basic taste test (Van Gemert, 1985) was used to test for ageusia [insensitive to all tastes or to a specific taste quality].The subjects first received five cups with the following solutions: sweet (10 g saccharose/l), sour (0.8 g citric acid/l), salty (2 g sodium chloride/l), bitter (1 g caffeine/l) and neutral (tap water). They had 5 min to learn these tastes. Next, they received each taste twice in another 10 cups that were labelled with a three-digit code. Subjects with more than two incorrect responses for all tastes or with two incorrect responses for the same basic taste were not admitted to the panel. By means of these two tests people with an abnormality in taste/smell perception were excluded from participation in the experiment but not people with an age-related impairment in taste/smell.

After screening and checking for motivation and availability on the days of testing, 20 young subjects and 23 elderly subjects were obtained. However, four young subjects and one elderly subject failed to complete the study due to other obligations and thus, the final panel of young adults consisted of 16 subjects [age range 18–35 (25.6 ± 3.7)], all norgeusmics (with normal taste) and normosmics (with normal smell). The final panel of elderly consisted of 22 subjects [age range 60–85 (68.5 ± 7.4)], all norgeusmics, 13 normosmics and 9 slight or medium hyposmics (with impaired smell). Both young and elderly subjects participated in the first and second experiment and in the texture sensitivity tests, whereas only the elderly performed the olfactory sensitivity test. The subjects were paid for their participation at the completion of all tests.

## Experiments 1 and 2

### Stimuli

Sweet vanilla waffles (Experiment 1) and savoury cheese waffles (Experiment 2) were used as basic solid food systems. When preparing waffles, three ingredients were varied according to a 2 · 2 · 2 full factorial design: two texture conditions, without and with a replacement of 25% wheat flour by potato starch (AVEBE Corp., Veendam, the Netherlands); two flavour conditions, with a low and a high level of cheese or vanilla flavour (IFF BV, Hilversum, the Netherlands); and two fat conditions, with a low and a high maize oil concentration (MAKRO, Arnhem, the Netherlands). Table 1 shows the ingredient composition of the waffle dough.

The waffles were baked for four minutes in a commercially available waffle hot plate (Cloer, Waffelautomat, Germany). After the samples cooled out they were stored in closed plastic containers at room temperature for at least 24 h. Five grams pieces of the waffles were served at room temperature.

*Table 1. Composition of the waffles dough.*

| Product | Texture | | Flavour | | Fat | |
|---|---|---|---|---|---|---|
| | Wheat flour (g) | Potato starch (g) | Vanilla flavour (ml) | Sugar (g) | Maize oil (ml) | Water (ml) |
| *Sweet waffle* | | | | | | |
| 1 | 300 | – | 6 | 80 | 100 | 300 |
| 2 | 300 | – | 6 | 80 | 160 | 240 |
| 3 | 300 | – | 12 | 80 | 100 | 300 |
| 4 | 300 | – | 12 | 80 | 160 | 240 |
| 5 | 225 | 75 | 6 | 80 | 100 | 300 |
| 6 | 225 | 75 | 6 | 80 | 160 | 240 |
| 7 | 225 | 75 | 12 | 80 | 100 | 300 |
| 8 | 225 | 75 | 12 | 80 | 160 | 240 |
| *Savoury waffle* | | | | | | |
| | | | Cheese flavour (g) | Salt (g) | | |
| 1 | 300 | – | 22.5 | 1.5 | 100 | 300 |
| 2 | 300 | – | 22.5 | 1.5 | 160 | 240 |
| 3 | 300 | – | 45 | 1.5 | 100 | 300 |
| 4 | 300 | – | 45 | 1.5 | 160 | 240 |
| 5 | 225 | 75 | 22.5 | 1.5 | 100 | 300 |
| 6 | 225 | 75 | 22.5 | 1.5 | 160 | 240 |
| 7 | 225 | 75 | 45 | 1.5 | 100 | 300 |
| 8 | 225 | 75 | 45 | 1.5 | 160 | 240 |

### Procedure

Prior to the experiment, all subjects underwent two training-sessions in which they were familiarized with the task, product type, chosen attributes and correct use of the rating scales. During this short training period the panelists assessed waffle pieces, but not from the particular waffles reported here. The actual experiment took place in two sessions per waffle type. In each sweet or savoury waffle session, all eight samples were assessed. The waffle pieces were all coded with random three-digit numbers and were presented in random order per person and per session. The same order was given to both age groups. Between samples, mineral water was used to rinse the palate. A piece of waffle, containing no flavour addition, was assessed at the start of every session as a dummy product to prevent the occurrence of first-order effects. Its results were later excluded from the data analysis.

First, pleasantness was assessed on a 100 mm horizontal visual analogue scale and, subsequently, the intensities of the texture and flavour attributes fattiness, airiness, dryness, elasticity, swallowing effort, after feel, sweetness (for sweet waffles only), vanilla flavour (for sweet waffles only), saltiness (for savoury waffles only) and cheese flavour (for savoury waffles only) were rated on visual analogue scales. The verbal anchors were Dutch terms that translate as ''very little/weak'' and ''very much/strong'' and were placed at 10% and 90% of the scale respectively.

## *Experiment 3*

### *Texture sensitivity tests*

Chewing efficiency was measured using two-coloured chewing gum (Bang Bang cola-lime, Joyco Group, Spain). It was chewed 20 times and then spit out. The degree of mixing was later compared to a standard picture scale ranging from score 0 to 8 (Fillion & Kilcast, 2001; Prinz, 1999).Oral tactile sensitivity was measured by an oral stereognosis test and a size discrimination test (Fillion & Kilcast, 2001).The oral stereognosis test involved the in-mouth identification of five alphabet letters made of icing sugar. The letters had to be identified with the aid of show-cards with 10 alternatives. A scoring system that took shape difficulty and shape similarity into account was then applied to allocate points to each of the five letters in order to get a total score ranging from 0 to 15.The particle size discrimination test consisted of three pairs of powdered sugar of different grades. The subjects had to recognize within each pair the one with the finest particle size. Points ranging from 0 to 6 were given on the basis of correct identification and difficulty of the size difference.

### *Olfactory test*

The European Test of Olfactory Capabilities (ETOC) was used to measure the olfactory performance of the elderly (Thomas-Danguin et al., 2003). It contains 16 sets of four vials. The vials are presented in sets of four (called blocks).In a block, only one vial contains an odour, the other three are odourless. The subjects had to smell the contents of all four vials and indicate subsequently which of the four vials contains an odorant (detection). Next, they had to select from four possible descriptors the one that best described the quality of the perceived odour (identification). For each correct odour detection one point was given. When the odour was also identified correctly another point is given, resulting in possible scores ranging from 0 to 32. Correct identification but wrong detection does result in zero points.

### *Data analysis (Experiments 1–3)*

The average of the two tasting sessions was used in the analyses, since no significant replication effect was observed. For the investigation of main effects and interaction effects of age on product perception and pleasantness, univariate repeated measures analysis of variance (ANOVA) was conducted per attribute, with age as between subjects factor and texture, flavour and fat as within-subjects factors. The analyses of variance were performed using SPSS v.11.0 (SPSS Inc. Chicago, IL 60611, USA). Only results with an observed power > 0.70 and a significance level of $\alpha \leq 0.05$ are reported in the results section. Results with an observed power below 0.70, but a significance level of $\alpha \leq 0.05$ are discussed as tendencies.

Traditional conjoint analysis was conducted on the pleasantness ratings of each person in order to estimate the relative factor importance of texture, flavour and fat on food appreciation for each individual. Conjoint analysis is a multivariate technique that enables the researcher to obtain information on the extent to which the experimentally manipulated factors contributed to food appreciation of a person (Hair et al., 1998). In order to summarize this contribution (factor importance) for different groups, the factor importance for each individual was computed and then an average, as recommended by Orme (2002). Conjoint analysis is often used in market research studies in which there are generally about 150–1200 respondents. In the current study, with 38 judges, conjoint analysis was used as an investigational tool to study whether or not these elderly and young individuals differ in the influence of texture, flavour and fat on their food appreciation. It is not the intention to apply these results to the population at large.

The effect of age on the different texture tests was analysed using one-way ANOVA. The elderly subjects were then split at a median point into two subgroups ''poor performance'' and ''good performance'' according to their performance in each of the chewing efficiency, letter recognition, particle size and olfactory tests and the effect of their performance on intensity ratings was analysed by univariate repeated measures ANOVA.

# Results

## Experiment 1: sweet waffles

The main effects of the replacement of 25% wheat flour by potato starch were a decrease in perceived fattiness [$F$ (1, 36) = 16.29, $P < 0.001$], and an increase in perceived elasticity [$F$ (1, 36) = 6.44, $P < 0.016$], and in dryness [$F$ (1, 36) = 32.55, $P < 0.001$]. The main effect of increasing the vanilla flavour concentration was an increase in perceived vanilla taste [$F$ (1, 36) = 13.63, $P < 0.001$]. The main effect of the increase in fat concentration was an increased perception of fattiness [$F$ (1, 36) = 8.10, $P < 0.007$], elasticity [$F$ (1, 36) = 23.99, $P < 0.001$], swallowing effort [$F$ (1, 36) = 9.94, $P < 0.003$], after feel [$F$ (1, 36) = 12.56, $P < 0.001$], and sweetness [$F$ (1, 36) = 12.63, $P < 0.001$] and a decreased perception of airiness [$F$ (1, 36) = 12.94, $P < 0.001$] and dryness [$F$ (1, 36) = 50.01, $P < 0.001$].

The elderly and young differed in perception with respect to several attributes. The elderly perceived fattiness [$F$ (1, 36) = 8.91, $P < 0.005$], elasticity [$F$ (1, 36) = 6.56, $P < 0.015$], sweetness [$F$ (1,36) = 6.77, $P < 0.013$] and vanilla flavour [$F$ (1, 36) = 10.66, $P < 0.002$] of the sweet waffles as less intense than did the young (Fig.1 (a)).

The replacement of 25% wheat flour by potato starch reduced the perceived airiness of the sweet waffles for the elderly only [$F$ (1, 36) = 7.50, $P < 0.010$]. No texture–flavour, fat–flavour or texture–fat interactions were observed.

The relative importance of the factors texture, flavour and fat on pleasantness ratings of each subject is shown in Table 2a. Both elderly and young subjects demonstrated a tendency to prefer the low fat sweet waffles prepared with pure wheat flour. The majority of the young expressed a preference for the lower flavour concentration, whereas no clear tendency could be observed for the elderly with respect to the flavour manipulation. Finally , looking at the groups' means, there were no indications of age related differences in the contributions of texture, flavour and fat to food appreciation.

## Experiment 2: savoury waffles

The following main effects of the factors texture, flavour and fat on the savoury waffle samples were observed. The replacement of 25% wheat flour by potato starch decreased the perceived fattiness [$F$ (1, 36) = 10.20, $P < 0.003$], airiness [$F$ (1,36) = 22.29, $P < 0.001$] and increased the perceived dryness [$F$ (1, 36) = 65.08, $P < 0.001$]. Increasing the cheese flavour concentration increased the perception of airiness [$F$ (1, 36) = 18.34, $P < 0.001$], cheesiness [$F$ (1, 36) = 54.53, $P < 0.001$], and saltiness [$F$ (1, 36) = 44.65, $P < 0.001$] and it decreased the perceived elasticity [$F$ (1, 36) = 30.94, $P < 0.001$] and dryness [$F$ (1, 36) = 29.13, $P < 0.001$]. Increasing the fat concentration increased the perceived fattiness [$F$

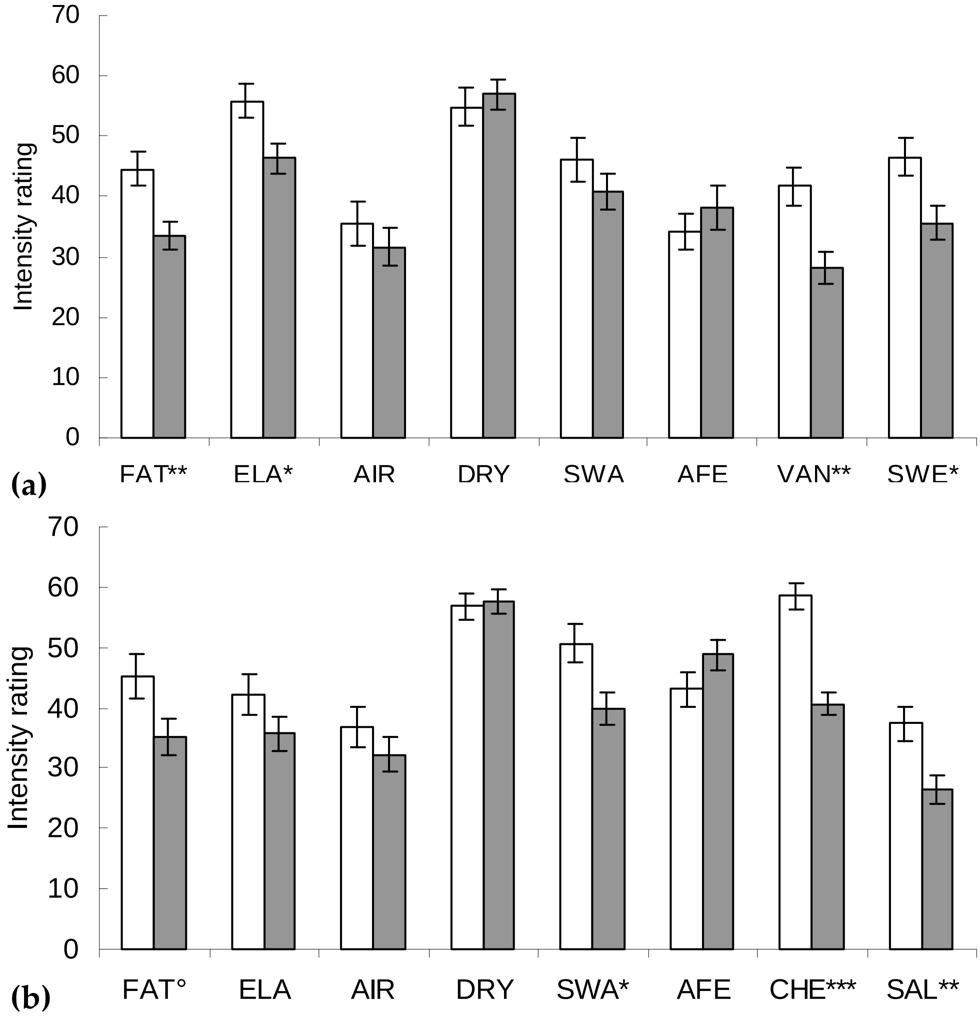


*Figure 1. Mean intensity ratings (±SEM) of fattiness (FAT), elasticity (ELA), airiness (AIR), dry (DRY), swallowing effort (SWA), after feel (AFE), vanilla/cheese flavour (VAN/CHE) and sweetness/saltiness (SWE/ SAL) in (a) sweet waffles and (b) savoury waffles by the elderly (filled bars) and the young (unfilled bars). O Trend, *p <= 0.05, **p <= 0.01, ***p <= 0.001.*

(1,36) = 4.45, $P < 0.042$], swallowing effort [$F$ (1, 36) = 16.70, $P < 0.001$], after feel [$F$ (1, 36) = 9.03, $P < 0.005$], and saltiness [$F$ (1, 36) = 12.15, $P < 0.001$] and it decreased the perceived airiness [$F$ (1, 36) = 11.31, $P < 0.002$] and dryness [$F$ (1, 36) = 51.27, $P < 0.001$].
The elderly and young differed in perception with respect to several attributes. The elderly rated the swallowing effort [$F$ (1, 36) = 6.63, $P < 0.014$], cheese flavour [$F$ (1, 36) = 39.61, $P < 0.001$] and saltiness [$F$ (1, 36) = 8.44, $P < 0.006$] of the savoury waffles as less intense than the young (Fig.1 (b)). Furthermore, a tendency (observed power <0.70) for lower fattiness ratings by the elderly was observed in the cheese waffles [$F$ (1, 36) = 4.40, $P < 0.043$]. Texture–flavour interaction played a role in the perception of cheesiness. More cheese flavour was perceived in waffles with a 25% replacement of wheat flour by

*Table 2a. Sweet waffles - traditional conjoint analysis: the factor importance [in %] of flavour, texture and fat on pleasantness per subject and per age group [mean].*

| | | Young subject no. | | | | | | | | | | | | | | | | | | | | | | Mean | Frequency | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | X | X | X | X | X | X | | + | 0 | - |
| Texture (%) | | 61.5 | 50.0 | 50.0 | 16.7 | 75.0 | 0.0 | 33.3 | 50.0 | 41.7 | 36.4 | 60.0 | 30.0 | 54.5 | 61. 5 | 66.6 | 12.5 | | | | | | | 43.7 | | | |
| Starch | None | + | + | + | + | + | 0 | + | + | + | + | - | + | + | + | + | - | | | | | | | | 13 | 1 | 2 |
| | 25% | - | - | - | - | - | - | - | - | - | - | + | - | - | - | - | + | | | | | | | | 2 | 1 | 13 |
| Flavor (%) | | 38.5 | 37.5 | 25.0 | 16.7 | 25.0 | 14.3 | 22.3 | 14.3 | 41.7 | 45.5 | 20.0 | 30.0 | 27.3 | 23.1 | 16.7 | 25.0 | | | | | | | 26.4 | | | |
| Vanilla | Low | + | + | + | + | + | + | + | - | + | - | - | + | + | - | + | - | | | | | | | | 11 | 0 | 5 |
| | High | - | - | - | - | - | - | - | + | - | + | + | - | - | + | - | + | | | | | | | | 5 | 0 | 11 |
| Fat (%) | | 0.0 | 12.5 | 25.0 | 66.6 | 0.0 | 85.7 | 44.4 | 35.7 | 16.6 | 18.1 | 20.0 | 40.0 | 18.2 | 15.4 | 16.7 | 62.5 | | | | | | | 29.9 | | | |
| Oil | Low | 0 | - | + | + | 0 | + | - | + | + | + | + | - | + | + | + | + | | | | | | | | 11 | 2 | 3 |
| | High | 0 | + | - | - | 0 | - | + | - | - | - | - | + | - | - | - | - | | | | | | | | 3 | 2 | 11 |
| | | Elderly subject no. | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | | + | 0 | - |
| Texture (%) | | 42.8 | 44.4 | 40.0 | 42.9 | 50.0 | 8.7 | 28.6 | 22.7 | 14.3 | 0.0 | 16.7 | 28.6 | 61.5 | 25. 0 | 38.9 | 100 | 32.0 | 21.1 | 25.0 | 88.9 | 33.3 | 65.0 | 37.7 | | | |
| Starch | None | - | + | - | - | + | - | + | + | + | 0 | + | + | + | - | + | + | + | + | - | + | + | - | | 14 | 1 | 7 |
| | 25% | + | - | + | + | - | + | - | - | - | 0 | - | - | - | + | - | - | - | - | + | - | - | + | | 7 | 1 | 14 |
| Flavor (%) | | 28.6 | 0.0 | 30.0 | 35.7 | 50.0 | 43.5 | 14.3 | 22.7 | 35.7 | 0.0 | 66.6 | 28.6 | 30.8 | 33. 3 | 44.4 | 0.0 | 40.0 | 36.8 | 25.0 | 0.0 | 58.3 | 15.0 | 29.1 | | | |
| Vanilla | Low | - | 0 | - | - | + | - | - | + | + | 0 | - | + | + | - | 0 | 0 | - | + | + | 0 | + | - | | 9 | 5 | 8 |
| | High | + | 0 | + | + | - | + | + | - | - | 0 | + | - | - | + | 0 | 0 | + | - | - | 0 | - | + | | 8 | 5 | 9 |
| Fat (%) | | 28.6 | 55.6 | 30.0 | 21.4 | 0.0 | 47.8 | 57.1 | 54.6 | 50.0 | 100 | 16.7 | 42.8 | 7.7 | 41. 7 | 16.7 | 0.0 | 28.0 | 42.1 | 50.0 | 11.1 | 8.3 | 20.0 | 33.2 | | | |
| Oil | Low | - | + | - | - | 0 | + | + | + | + | + | - | + | + | + | 0 | 0 | + | + | - | - | + | + | | 13 | 3 | 6 |
| | High | + | - | + | + | 0 | - | - | - | - | - | + | - | - | - | 0 | 0 | - | - | + | + | - | - | | 6 | 3 | 13 |

+, indicates a positive part-worth estimate; –, a negative part-worth estimate; 0, indicates no contribution. The frequency of the +/0/- part-worth estimates is summed up.

*Table 2b. Savoury waffles - traditional conjoint analysis: the factor importance [in %] of flavour, texture and fat on pleasantness per subject and per age group [mean].*

| | | Young subject no. | | | | | | | | | | | | | | | | | | | | | | Mean | Frequency | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | X | X | X | X | X | X | | + | 0 | - |
| Texture (%) | | 20.0 | 60.0 | 25.0 | 25.0 | 6.2 | 15.8 | 9.1 | 46.6 | 9.1 | 5.8 | 44.4 | 46.4 | 16.7 | 8.3 | 21. 1 | 16.6 | | | | | | | 23.5 | | | |
| Starch | None | + | + | + | + | + | - | + | + | + | + | + | + | + | + | + | + | | | | | | | | 15 | 0 | 1 |
| | 25% | - | - | - | - | - | + | - | - | - | - | - | - | - | - | - | - | | | | | | | | 1 | 0 | 15 |
| Flavor (%) | | 80.0 | 0.0 | 75.0 | 25.0 | 50.0 | 84.2 | 72.7 | 26.7 | 63.6 | 47.1 | 55.6 | 28.6 | 16.7 | 25. 0 | 57.8 | 41.7 | | | | | | | 46.9 | | | |
| Cheese | Low | + | 0 | + | - | + | + | + | - | - | - | - | + | - | + | + | - | | | | | | | | 8 | 1 | 7 |
| | High | - | 0 | - | + | - | - | - | + | + | + | + | - | + | - | - | + | | | | | | | | 7 | 1 | 8 |
| Fat (%) | | 0.0 | 40.0 | 0.0 | 50.0 | 43.8 | 0.0 | 18.2 | 26.7 | 27.3 | 47.1 | 0.0 | 25.0 | 66.6 | 66.7 | 21. 1 | 41.7 | | | | | | | 29.6 | | | |
| Oil | Low | 0 | + | 0 | + | + | 0 | + | + | - | + | 0 | - | + | + | + | - | | | | | | | | 9 | 4 | 3 |
| | High | 0 | - | 0 | - | - | 0 | - | - | + | - | 0 | + | - | - | - | + | | | | | | | | 3 | 4 | 9 |
| | | Elderly subject no. | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | | + | 0 | - |
| Texture (%) | | 10.0 | 10.0 | 11.8 | 56.2 | 20.0 | 20.0 | 13.6 | 66.6 | 30.8 | 66.7 | 12.5 | 43.7 | 33.3 | 39. 3 | 40.0 | 58.3 | 75.0 | 33.3 | 14.3 | 27.8 | 71.4 | 80.0 | 37.9 | | | |
| Starch | None | + | + | + | + | + | + | + | + | + | + | - | + | + | + | + | + | + | + | + | - | + | + | | 20 | 0 | 2 |
| | 25% | - | - | - | - | - | - | - | - | - | - | + | - | - | - | - | - | - | - | - | + | - | - | | 2 | 0 | 20 |
| Flavor (%) | | 10.0 | 80.0 | 0.0 | 43.8 | 30.0 | 40.0 | 72.8 | 16.7 | 30.8 | 0.0 | 25.0 | 50.0 | 14.8 | 35. 7 | 26.7 | 33.3 | 8.3 | 50.0 | 57.1 | 66.7 | 28.6 | 20.0 | 33.7 | | | |
| Cheese | Low | + | - | 0 | + | - | + | - | - | + | 0 | - | - | - | - | - | - | - | - | - | - | - | - | | 4 | 2 | 16 |
| | High | - | + | 0 | - | + | - | + | + | - | 0 | + | + | + | + | + | + | + | + | + | + | + | + | | 16 | 2 | 4 |
| Fat (%) | | 80.0 | 10.0 | 88.2 | 0.0 | 50.0 | 40.0 | 13.6 | 16.7 | 38.4 | 33.3 | 62.5 | 6.3 | 51.9 | 25. 0 | 33.3 | 8.4 | 16.7 | 16.7 | 28.6 | 5.5 | 0.0 | 0.0 | 28.4 | | | |
| Oil | Low | - | - | + | 0 | + | + | + | - | + | + | + | - | + | + | + | + | - | - | + | - | 0 | 0 | | 12 | 3 | 7 |
| | High | + | + | - | 0 | - | - | - | + | - | - | - | + | - | - | - | - | + | + | - | + | 0 | 0 | | 7 | 3 | 12 |

+, indicates a positive part-worth estimate; –, a negative part-worth estimate; 0, indicates no contribution. The frequency of the +/0/- part-worth estimates is summed up.

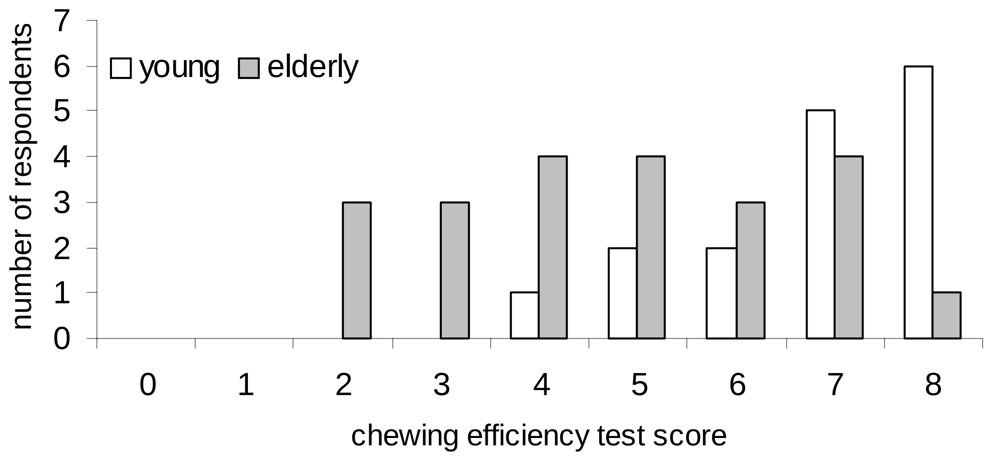


*Figure 2. Results of the chewing efficiency test for the young and the elderly. Number of respondents obtaining a specific score as a function of chewing efficiency (max.score = 8).*

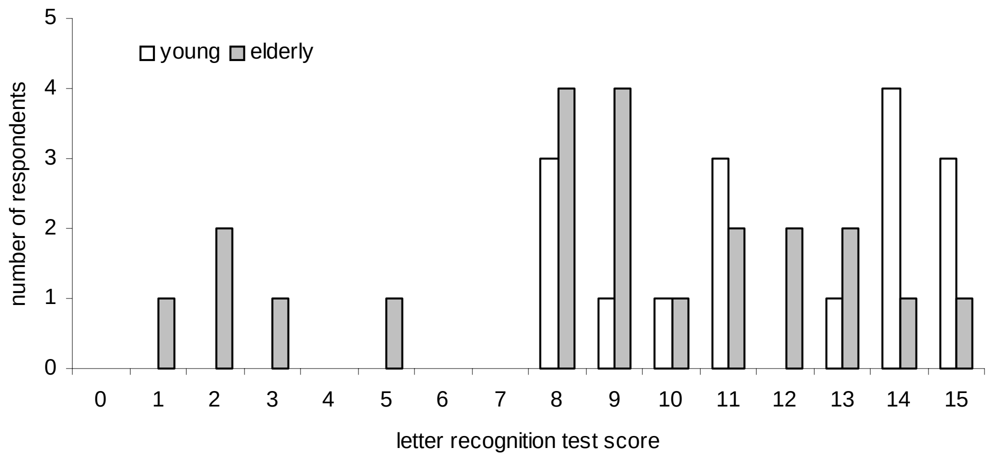


*Figure 3. Results of the letter recognition test for the young and the elderly. Number of respondents obtaining a specific score as a function of correct letter recognition (max.score = 15).*

potato starch than in waffles with 100% wheat flour [$F$ (1, 36) = 7.29, $P < 0.010$]. Age was found to have no influence on this interaction effect. No fat–flavour or texture–fat interactions were observed.

The relative importance of texture, flavour and fat on pleasantness ratings of each subject is shown in Table 2b. Both elderly and young subjects demonstrated a tendency to prefer the low fat savoury waffles prepared with pure wheat flour. The majority of the elderly expressed a preference for the higher cheese flavour concentration, whereas no clear tendency could be observed for the young with respect to the flavour manipulation. Finally, looking at the groups' means, flavour seems to contribute more to the pleasantness ratings of the young subjects than of the elderly subjects.

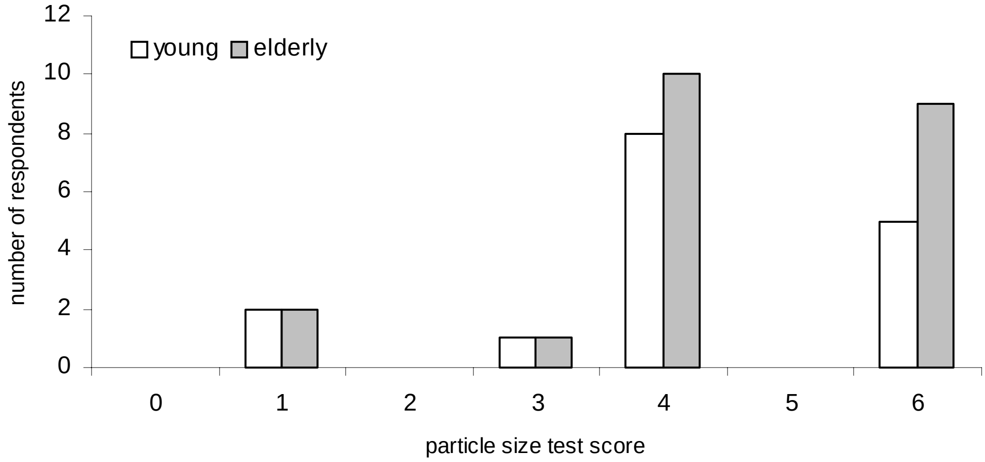


*Figure 4. Results of the particle size test for the young and the elderly. Number of respondents obtaining a specific score as a function of correct size discrimination (max.score = 6).*

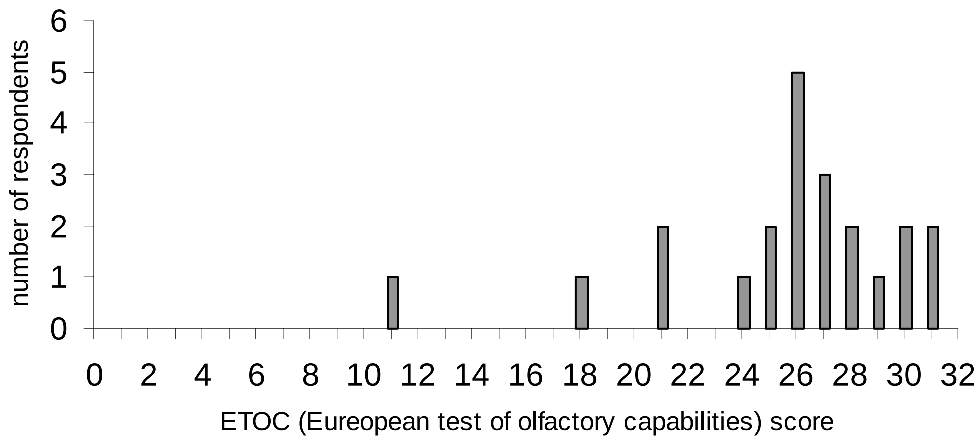


*Figure 5. Results of the ETOC for the elderly.Number of respondents obtaining a specific cumulative score as a function of correct odour detection and identification (max.score = 32).*

## Experiment 3: texture and olfactory sensitivity tests

The young outperformed the elderly in chewing efficiency [$F$ (1, 36) = 14.71, $P < 0.001$] and in letter recognition [$F$ (1, 36) = 7.44, $P < 0.010$]. These results are shown in Figs.2 and 3 respectively. In contrast, the elderly and the young did not differ in their ability to detect differences between sugar particle sizes (Fig.4 ).

In the olfactory test for the elderly (Fig.5 ), the mean cumulative score was 25.59 (±4.50 S.D.). The mean score for detection was 14.32 (±2.01 S.D.) and for identification was 11.27 (±2.80 S.D.). Thus on average the elderly detected 14 odours out of 16 and identified 11 out of 16.

*Table 3. Details of the elderly subgroups, split according to their performance in the chewing efficiency, letter recognition, particle size and olfactory tests.*

| | | | Good performance | | Poor performance | |
|---|---|---|---|---|---|---|
| Sensitivity test | Range of outcome | Median cut-off | Number of subjects | Mean age (±S.D.) | Number of subjects | Mean age (±S.D.) |
| Chewing efficiency | 0–8 | ≥ 5 | 12 | 68.1 (±7.4) | 10 | 67.5 (±5.8) |
| Letter recognition | 0–15 | ≥ 9 | 12 | 66.8 (±6.1) | 10 | 69.1 (±7.2) |
| Particle size | 0–6 | ≥ 5 | 9 | 70.0 (±7.8) | 13 | 66.4 (±5.3) |
| ETOC | 0–32 | ≥ 27 | 10 | 65.4 (±4.8) | 12 | 69.9 (±7.2) |

### *Relationship between texture sensitivity or olfactory sensitivity and perceived intensities for the elderly*

Table 3 shows the details of the elderly sensitivity subgroups. No significant differences in intensity responses were found when the elderly were split at a median cutoff point according to their performance in texture sensitivity tests into good and poor performance groups. However, splitting the elderly into two groups according to their olfactory sensitivity revealed significant flavour perception differences for both waffle types (Fig.6). Compared to the elderly with poor olfactory performance, the elderly with good olfactory performance perceived higher flavour intensities both in the sweet waffles [$F$ (1, 20) = 7.16, $P < 0.015$] and in the savoury waffles [$F$ (1,20) = 7.52, $P < 0.013$].

## Discussion

The present study used commercial-type solid foods, as opposed to model systems or solutions, to study the perception of texture and flavour in two healthy age groups. These foods allow us to draw conclusions on the effect of age on waffle perception and appreciation, but they may or may not be relevant for other foods.

Both liking and attribute assessments were asked in the present study. According to Stone & Sidel (1993), this may introduce a bias in affective testing. However, recent


*Figure 6. Mean intensity vanilla and cheese flavour ratings (±SEM) of the elderly split into good and poor performance groups according to their performance in the ETOC.*

research has demonstrated that this concern only holds true for the inclusion of attribute liking and ''just-about-right'' assessments but not for the inclusion of intensity assessments (Popper et al., 2004).

The elderly differed from the young in their ratings of two out of six texture attributes and all flavour/taste attributes. In both waffle types, the elderly perceived the taste attributes (sweet/salty) as less intense than did the young. This finding is consistent with the work of Mojet et al. (2003), who reported that the elderly perceived both the salty compounds, dissolved into tomato soup, and the sweet compounds, dissolved into chocolate drink, as less intense than did the young. In contrast, several other studies found no differences in the saltiness or sweetness perception when the compounds were added to a food (Drewnowski et al., 1996; Stevens & Lawless, 1981; Warwick & Schiffman, 1990; Zallen et al., 1990).

The flavour attributes (vanilla/cheese) were perceived as less intense by the elderly than by the young. This finding agrees with the results of the following studies. First, in bouillon and tomato soup, higher flavour concentrations were needed for the elderly in order to reach the same intensity given by the young (De Graaf et al., 1996). Secondly, in white cream soups, the elderly perceived both the mushroom flavour and the chicken flavour as less intense than the young (Kremer et al., 2005). Thirdly, odour and/or flavour perception is frequently reported to be impaired in the elderly (Murphy, 1983; Stevens et al., 1984; Stevens & Cain, 1987). Furthermore, when the elderly group was split into two sub-groups according to their olfactory acuity, the elderly in the low performing group perceived the flavour attributes even less intense.

Perceived fattiness of the sweet waffles was less pronounced for the elderly than for the young. A similar tendency was found for savoury waffles. Thus, fattiness perception might somehow be different in the two age groups. Two explanations are possible. First, mouth-feel sensations and taste/flavour sensations may be combined into fattiness perception (Yackinous & Guinard, 2000). Smell perception is frequently reported to be impaired in the elderly, which in turn may cause changes in the profiles of different sensations. As a result, fattiness could become reduced in the elderly. The second explanation may be that the elderly grew up with higher fat levels in foods (Löwik et al., 1998) and might be habituated to more fatty foods than the young. This finding agrees with the results of a previous study on age differences in the intensity perception of texture and flavour/taste attributes (Kremer et al., 2005) in which white cream soups were rated less creamy by the elderly than by the young.

The interaction effect found was not different for the elderly and for the young. Thus, the present study does not support the hypothesis that dissimilar deteriorations in the different senses inevitably lead to a difference in the integrated product concept for the elderly and the young. This finding does not confirm the results of a recent study in which such age-related differences in interaction effects were found (Kremer et al., 2005).It may be still too early to draw a final conclusion as only one interaction effect was observed in the present study, whereas several interaction effects were observed in the previous study. The extent of interaction may depend on the product and the stimuli used. For example, the oral processing of soup and waffles is very different, which may influence the occurrence of interaction effects. Such effects have also been shown to be highly concentration and compound specific (Pangborn et al., 1978). Such specificity is supported by the results of the present study, since the texture flavour interaction was found in the cheese-flavoured but not in the vanilla-flavoured waffles.

Pleasantness ratings are relatively low for both types of waffles. This is surprising as Dutch elderly people are thought to like waffles. The initial purpose of this study was to use samples that resemble commercial food products. This might not have been accomplished to the full extent, since on the one hand the sweet waffles seemed not to be as ''good'' as their well-known commercially available counterparts, and on the other hand the savoury waffles turned out to be too ''novel'' to be really liked. Nevertheless, the model waffles still allowed us to investigate by means of individually computed traditional conjoint analyses the relative importance of the factors flavour, texture and fat to food appreciation per person and per age group.

The factor flavour seemed to contribute more to the pleasantness ratings of the young subjects than of the elderly subjects in the savoury waffles. This finding is in accordance with the notion that the influence of texture on food perception and appreciation is increased for the elderly (Forde & Delahunty, 2002; Kälviäinen et al., 2003; Szczesniak, 1990). However, this tendency was not observed with the sweet waffles of the present study or with the soups in the previous study (Kremer et al., 2005). This suggests that with increasing age texture may become more important for pleasantness, but it also suggests that this cannot be generalized. Research data on this subject are still very limited; thus no definite conclusion can yet be drawn.

The waffle's flavour and texture were systematically manipulated, with the aim to increase food appreciation in the elderly. In previous studies, the enhancement of flavour has been reported to be a successful strategy to increase product liking in the elderly (Griep et al., 1997; Griep et al., 2000; Mathey et al., 2001; Schiffman & Warwick, 1993). In the present study, the elderly's appreciation was increased by the enhancement of cheese flavour only in the savoury waffles and not for vanilla in the sweet waffles. The success of flavour enhancement as a compensatory strategy may depend on the type of product and of flavour used. The explanation for this observation may be sought in product experience as sweet vanilla waffles are ''well-known'' to the Dutch consumers, whereas soft savoury cheese waffles are relatively novel. Such ''top-down'' effects of sensory concepts have been recently reported to affect the discrimination of odour sensations (Bult et al., 2001). This effect would also explain why so many elderly are not aware of their sensory losses and do not often report a decrease in their appreciation of food (Wysocki & Pelchat, 1993).

The young were more efficient in mastication than the elderly. This finding agrees with a recent study by Kälviäinen et al.(2003). Dental integrity is a prime regulator of masticatory performance since wearing dentures leads to significant alterations of chewing and mouth movements (Wayler et al., 1984). In the current study, only one person in the group of the elderly had intact dentition whereas the rest had at least some teeth absent and/or were wearing partial or even complete dentures.

Since the letter recognition test (Fillion & Kilcast, 2001) might measure cognitive abilities besides the oral stereognosis, the results of this test do not reveal whether decreased oral sensitivity or cognitive memory deficits with increasing age are the cause of more incorrect letter identifications of the elderly.

The elderly and the young did not differ in their detection of sugar crystal sizes. This finding is in agreement with a recent study by Kälviäinen et al. (2003). Also, other oral sensations, such as vibratory and thermal sensitivity, have been reported to remain relatively efficient with aging (Calhoun et al., 1992). This suggests that oral tactile sensitivity is not severely affected by age per se.

The mean olfactory scores of the elderly for the ETOC odour detection and identification tests in the present study are in line with recent publications (Koskinen et al., 2003; Koskinen & Tuorila, 2005; Thomas-Danguin et al., 2003).
The elderly with low olfactory sensitivity rated both vanilla and cheese flavour intensity as lower than the elderly with high olfactory sensitivity. On first sight, this finding suggests that orthonasal (from outside the nose) odour perception — measured by the ETOC — is a good predictor of retronasal (from inside the mouth) intensity ratings in the elderly. However, Duffy, et al. (1999) have pointed out that while good orthonasal olfaction may be necessary for good retronasal flavour perception, it is not sufficient. Other factors, such as oral health and dentition, were thought to impede release and retronasal transport of odours from the mouth to the olfactory receptors. Furthermore, Koskinen & Tuorila (2005) reported that performance in the ETOC was not related to retronasal flavour intensity ratings of complex foods in the elderly. Thus it seems too early to conclude, whether or not the measurement of orthonasal odour perception can predict retronasal flavour perception of the elderly.
No significant difference in intensity responses was found when the elderly were split at a median cut-off point into high and low texture sensitivity groups. Thus it seems that oral tactile sensitivity is not related to intensity ratings — at least in the present group of elderly.

## Conclusions

The notion that elderly attention generally shifts in food appreciation from the once dominant factor, flavour to other factors was not confirmed by the present study since a decrease in the importance of flavour in food appreciation was observed for the elderly in the savoury but not in the sweet waffles. The young were more efficient in chewing and they were better in oral letter recognition test than the elderly. Among the elderly, olfactory sensitivity influenced flavour intensity ratings, whereas texture sensitivity was not related to perception of sensory attributes. Furthermore, the elderly differed from the young in their perception of texture and flavour, but the observed texture–flavour interaction effect was not different for the elderly and young. Thus, the present study does not support the hypothesis that a different rate in the decline of the different senses with age will inevitably lead to a different integrated product concept.

## Acknowledgements

This work is a part of the ''HealthSense'' project (Healthy Ageing: How Changes in Sensory Physiology, Sensory Psychology and Sociocognitve Factors Influence Food Choice) and was carried out with financial support from the EU, Fifth Framework Programme 1998–2002 (QLK1-CT-1999-00010). Special thanks to Rudi van Doorn and Monique Theunis, for their assistance in conducting the study and to Dr. Eric Dransfield, for his useful comments on the manuscript.

# Chapter 4

## Compensation for age-associated chemosensory losses and its effect on the pleasantness of a traditional dessert and a novel drink

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Appetite, submitted

## Abstract

Differences between elderly subjects (n = 52, 60-85 years) and young subjects (n = 55, 18-35) in their food liking and their olfactory sensitivity were investigated. Two food systems were used: custard desserts as a well-known food and tomato-spirulina health drinks as a novel food. Flavor enhancement/enrichment, textural change, and/or irritant addition were incorporated as compensatory strategies into these foods. Food liking of the elderly was not generally increased by these compensatory strategies. For each compensatory strategy, subgroups were observed in which applied compensatory strategies led to an increase in product pleasantness. Age-associated losses in olfactory capabilities did not sufficiently explain differences in food liking. The present study does not support the assumption that age-related impairment in olfactory sensitivity will inevitably lead to changes in food liking.


## Introduction

Food intake declines with increasing age, a physiological phenomenon that has been described as the "anorexia of aging" syndrome (Morley, 2001). Until recently it was widely assumed that age-related impairment in chemosensory acuity would inevitably lead to changes in liking with increasing age and this would lead to modifications of elderly food choice and dietary behavior (see the critical review by Mattes, 2002). This sequence of assumptions was based on the observation that sensory acuity diminishes with age (Murphy, 1993) and on several reports that elderly subjects expressed a preference either for higher stimuli concentrations in aqueous solutions or for stronger flavored products (Schiffman & Warwick, 1993; De Graaf et al., 1996; Griep et al., 1997). However, ambiguous results were obtained in studies in which preference was assessed both in aqueous solutions and in products. On the one hand, elderly subjects were reported to demonstrate age-related differences in preference both in solutions and "real-life" products (Murphy & Withee, 1986; Drewnowski et al., 1996). On the other hand, although the elderly still seemed to prefer higher stimulus concentrations in solutions, their preferences for "real-life" food products were very similar to those of the young (Chauhan, 1989; De Graaf et al., 1994; Mojet et al., 2005). Furthermore, in recent studies no correlation was found between sensory capabilities and hedonic responses (Koskinen et al., 2003b; Issanchou, 2004; Forde & Delahunty, 2004; Kremer et al., in press). Thus, at present, the sequence of assumptions lacks sufficient support.

Nonetheless, despite this lack of evidence, the use of compensatory strategies, such as adding or increasing certain ingredients (e.g. flavors or irritants) or changing food tex-

ture, still aims to counteract age-associated sensory losses and to increase product pleasantness for the elderly.
Reports that the enhancement or enrichment of flavor increased product liking for the elderly (Schiffman & Warwick, 1993; Griep et al., 1997; Griep et al., 2000, Schiffman, 2000) were not confirmed when different flavor/taste levels were assessed (Koskinen et al., 2003b; Mojet et al., 2005; Kremer et al., 2005). The elderly had similar preferences to the young, instead of preferring the flavor-enhanced variants. Elderly people's flavor preferences for traditional waffle types were similar to those of young consumers but in novel waffle types they preferred the flavor-enhanced products (Kremer et al., in press). A possible explanation for this finding can be that the elderly are able to compensate for sensory losses with the help of earlier acquired product concepts. However, since research data on this subject are still very limited, no definite conclusion can yet be drawn.
The addition of an irritant below or just above threshold level has been suggested as another possible compensatory strategy as it is thought to provide another dimension to the eating experience of the elderly (Laska, 2001). So far, the addition of an irritant has either been reported to increase preference among small sub-groups of elderly (Forde & Delahunty, 2002; Forde & Delahunty, 2004) or to generally decrease preference for most elderly (Koskinen et al., 2003a).
Although a compensatory strategy by changing food texture (Clydesdale, 1991; Peleg, 1993; Ship, 1996, Forde & Delahunty, 2002) has been suggested little research has been conducted and specific advice is lacking. The addition of a thickener to purées increased the liking and intake for nursing home residents (Cassens et al., 1996). However, the results may not be generalized to the group of healthy, community dwelling elderly.
Contradictory results have been obtained for the notion that the dominant modality in food appreciation may change during aging. Texture manipulations had a higher impact on pleasantness of the elderly than of the young in muesli, in soups and in waffles (Kälviäinen et al., 2002, Forde & Delahunty, 2002, Kremer et al., in press). However, in yoghurt, texture contributed less to pleasantness ratings of the elderly (Kälviäinen et al., 2003). In white cream soups and sweet waffles the relative importance of texture and flavor to appreciation was similar in both young and elderly (Kremer et al., 2005, Kremer et al., in press). Thus, the importance of food characteristics to its appreciation seems to be product dependent.
The present study investigates whether or not elderly and young differ in their food liking and whether or not compensatory strategies would be beneficial in increasing

food enjoyment for the elderly. Because any effect of compensation for sensory losses is affected by prior product experience (Mojet et al., 2005; Kremer et al., in press), preference was assessed in one well known (custard desserts) and one novel (tomato-spirulina health drink) food. Several compensatory strategies were incorporated into these foods. The influence of age on the relative importance of these strategies was also studied. An olfactory sensitivity test was included as subjects with poor olfactory sensitivity may respond differently to compensatory strategies than those with good olfactory sensitivity.

# Methods

## *Subjects*

A total of 55 young and 55 elderly subjects were recruited but 3 of the elderly were unable to complete the tests and their results were therefore excluded. The remaining elderly (36 females and 16 males, mean age 71.3, range 61-86 years) were community dwelling, lived independently and prepared their meals at home. They all visited service centers for the elderly either in Ede or in Utrecht, The Netherlands, and they were recruited with the help of staff members working there. The young subjects (31 females and 24 males, mean age 22.7, range 18-35 years) were recruited from the staff and students of the University of Wageningen. The subjects participated in four tasting sessions each lasting approximately 1 hour and were paid for completing the tests.

## *Samples*

### *Traditional custard desserts*

Custard desserts were used to study the compensatory strategies "texture change", "flavor enrichment" and "flavor enhancement". For one batch, 70 g of custard powder (Paradies Crème, Dr. Oetker KG, Bielefeld, Germany) was mixed with 300 ml full fat milk and three additional ingredients according to a 3x3x3 full factorial design. Texture was changed by adding zero, low [2g] and high [6g] amounts of cream topping (Campina Nederland, Woerden, the Netherlands). Flavor enrichment was achieved by adding zero, low [600 μl] and high [1800 μl] amounts of cherry flavor (Ducros, Avignon, France) and cream flavor enhancement by adding zero, low [7 μl] and high [21μl] amounts of a mixture of diacetyl (45% Vol.), delta-decalactone (45% Vol.) and butyric acid (10% Vol.), all obtained from IFF B.V., Hilversum, the Netherlands.

### Novel health drinks

Flavor enrichment and irritant addition were applied to a tomato juice (EDAH, Nederland) based health drink with added crushed spirulina (OTC Pharma, BV, Gorinchem, Nederland) in a 3x3 full factorial design. Flavor enrichment was done by adding zero, low [750 µl] and high [1500 µl] levels of lemon flavor (Boukje, the Netherlands) and irritant additon by adding zero, low [1.5 µl] and high [5 µl] concentration of capsicum (IFF B.V., Hilversum, the Netherlands) to 500ml of the drink. All products were prepared at least 18 hours before serving, were placed in small plastic cups with lids and stored overnight at in a chill room at 4°C. One hour before serving, all samples were taken out of the chill room and they were served at room temperature.

## Procedure

The tasting sessions for the young subjects were held in meeting rooms of the University of Wageningen and those for the elderly in clubrooms in the service centers. Pleasantness was assessed on a 130mm horizontal visual analogue scale. Tests were conducted once a week over a period of four weeks. Per session, subjects first received randomized sub-sets of the custard desserts followed by randomized sub-sets of the health drink samples. The samples were all coded with random three-digit numbers and were presented in random order per person. The same randomization was applied for the two age groups. After completing the four weeks test cycle, each subject had assessed all 27 custard desserts and 8 tomato drinks once. Panelists were asked to neutralize with water and cream crackers between the samples. Inter-stimulus intervals were approximately 2 min.

## Olfactory test

The European test of olfactory capabilities (ETOC) was used to measure the olfactory performance in the final session (Thomas-Danguin et al., 2003). Sixteen food and none-food odors were presented in 16 sets. Each set consisted of 1 odor-filled vial and 3 empty vials. The subjects indicated which of the 4 vials contained an odor (detection) and then, they selected one from a list of four descriptors (identification). For each correct odor detection one point was given. Only when the odor was identified correctly was another point given for correct identification. This gave scores ranging from 0 to 32.

## Data analysis

Main effects of age, compensatory strategy and age by compensatory strategy interaction effects on pleasantness ratings were determined by univariate repeated measures

analysis of variance (ANOVA) with age as between-subjects factor and the experimentally manipulated factors as within-subjects factors. To correct the model for deviations of sphericity, the degrees of freedom were adjusted with the Huynh-Feldt epsilon. Post hoc tests were performed using the least-significant difference (LSD) method. The analyses of variance were performed using SPSS v. 11.0 (SPSS Inc. Chicago, IL 60611, USA).
Conjoint analysis was conducted on ranked pleasantness ratings of each person to estimate the relative importance of the experimentally manipulated factors on the food pleasantness of the individual. Conjoint analysis is a multivariate technique that enables the researcher to quantify the extent to which the experimentally manipulated factors contributed to food appreciation of a person (Hair et al., 1998). In each age group, the factor importances) for each individual were computed and averaged, as recommended by Orme (2002). In addition, within each experimental factor, the influences of the different levels on the pleasantness ratings were determined as part worth estimates, e.g. a factor level with a positive part-worth estimate will have influenced the pleasantness ratings positively and the contrary (Hair et al., 1998). The frequencies of +/0/- part worth estimates were collected and their differences between the two age groups were assessed by chi-square.
The cumulative scores (CS) of the olfactory test (ETOC) from the elderly were compared to those of the young by one-way analysis of variance. Then, the elderly were divided into three subgroups separated at the 33.3 and 66.6 percentile of the CS distributions. These subgroups were referred to as "high" (CS 27-32, n = 15), "medium" (CS 21-26, n = 19) and "low" (CS 0-20, n = 18) odor sensitive. The effect of performance in ETOC on the pleasantness ratings and factor importance was tested by univariate repeated measures analysis of variance (ANOVA) with olfactory sensitivity as between-subjects factor and the experimentally manipulated factors as within-subjects factors.

# Results

## *Traditional custard dessert*

Adding cream topping to the custard desserts increased pleasantness [$F$ (2, 210) = 5.492, $P$ <0.005] for both zero versus low addition (p < 0.022) and zero versus high addition (p < 0.003). Flavor enrichment had no significant effect, whereas the flavor enhancement decreased [$F$ (1.6, 172.4) = 23.307, $P$ <0.001] pleasantness at the low concentration (p < 0.035) and further decreased it with the high flavor addition (p < 0.001). No significant interaction effect with age was observed.

*Table 1. Mean factor importance of different compensatory strategies on pleasantness of custard desserts and health drinks for the young and elderly subjects. The frequency of the +/-/o part-worth estimates is cumulated. + indicates a positive part-worth estimate, - a negative part-worth estimate and o indicates no contribution.*

| Product | Factor | Level | Young (n = 55) Part-worth estimates (frequencies) + | 0 | - | Factor importance (%) | Elderly (n = 52) Part-worth estimates (frequencies) + | 0 | - | Factor importance (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Zero | 25 | 1 | 29 | | 19 | 2 | 31 | |
| | Texture change | Low | 25 | 0 | 30 | 30.2 | 27 | 0 | 25 | 29.5 |
| | | High | 38 | 0 | 17 | | 25 | 2 | 25 | |
| | | Zero | 33 | 0 | 22 | | 23 | 1 | 28 | |
| Custard dessert | Flavor enrichment | Low | 22 | 0 | 33 | 30.2 | 31 | 0 | 21 | 29.6 |
| | | High | 21 | 1 | 33 | | 21 | 1 | 30 | |
| | | Zero | 34 | 1 | 20 | | 33 | 0 | 19 | |
| | Flavor enrichment | Low | 30 | 0 | 25 | 39.6 | 34 | 0 | 18 | 40.9 |
| | | High | 16 | 0 | 39 | | 10 | 1 | 41 | |
| | | Zero | 32 | 5 | 18 | | 20 | 8 | 24 | |
| Health drink | Flavor enrichment | Low | 20 | 3 | 32 | 45.6 | 25 | 2 | 25 | 46.2 |
| | | High | 25 | 2 | 28 | | 23 | 6 | 23 | |
| | | Zero | 39 | 3 | 13 | | 29 | 3 | 20 | |
| | Irritant addition | Low | 17 | 4 | 34 | 54.4 | 30 | 1 | 21 | 53.8 |
| | | High | 21 | 3 | 31 | | 20 | 3 | 29 | |

The relative importance of the factors texture change (cream topping), flavor enrichment (cherry flavor) and flavor enhancement (cream flavor) on pleasantness ratings and the frequencies of the +/0/- part worth estimates are shown in Table 3 for the elderly and the young. The contributions of the factors texture, flavor enrichment and flavor enhancement to food appreciation did not differ between the two age groups. The most influential factor was the flavor enhancement, with lesser and equal contributions from flavor enrichment and texture. Three significant differences between the two age groups were found using the part-worth frequency estimates. Firstly, changing texture by the addition of high-level cream topping had a positive influence on pleasantness for the majority of the young but for only half the elderly [d.f. = 1, $X^2 = 3.98$, $p < 0.05$]. Secondly, flavor enrichment at a low concentration had a positive influence on pleasantness [d.f. = 1, $X^2 = 4.27$, $p < 0.05$] for the majority of the elderly, but decreased preference for the young. Thirdly, the flavor enhancement at a low concentration had a positive influence on pleasantness for the majority of the elderly but for only half of the young [d.f. = 1, $X^2 = 4.28$, $p < 0.05$].

## *Novel health drink*

The flavor enrichment influenced pleasantness [$F$ (1.98, 207.7) = 3.960, $P$ <0.021]. The addition of the lemon flavor at low concentration decreased the pleasantness of the health drinks compared to drinks without flavor enrichment ($p < 0.013$) and to drinks with flavor enrichment at high concentration ($p < 0.049$). No age by flavor enrichment interaction was observed.

The age by irritant addition interaction was significant [$F$ (1.76, 184.5) = 3.795, $P$ <0.029]. The addition of an irritant at low and high concentration both decreased the pleasantness of the drinks for the young, whereas the elderly liked equally the drinks with no or low irritant addition and only expressed a dislike for drinks with higher irritant addition (Figure 1).

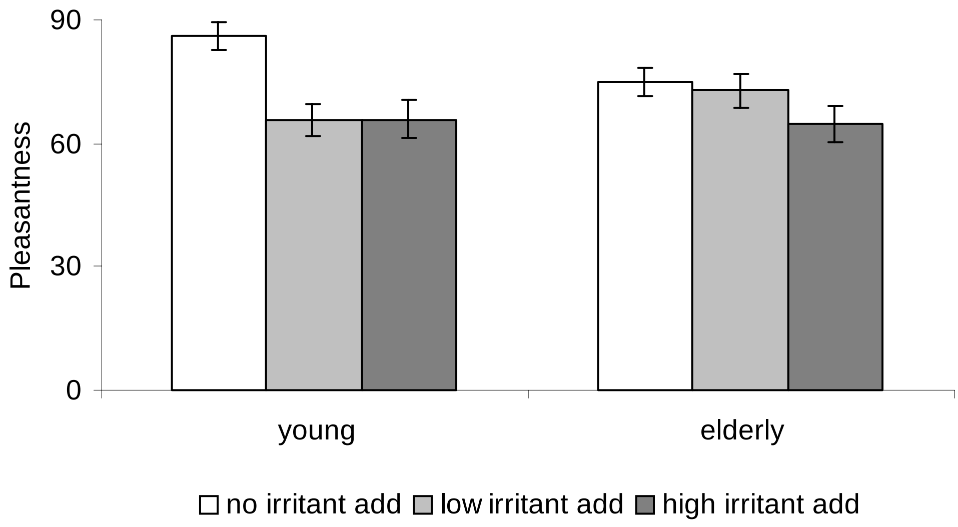


*Figure 1. Mean pleasantness ratings (±SEM) in health drinks with no, low and high concentration of an irritant addition by the elderly and the young.*

The importance of flavor enrichment (lemon flavor) and irritant addition (capsicum) on pleasantness ratings and the frequencies of the +/0/- part worth estimates are shown in Table 1. The contribution of the flavor enrichment and irritant addition to food appreciation was similar in both age groups. Looking at the frequencies of the part-worth estimates, one significant difference between the two age groups was found. Low concentration increased pleasantness for the majority of the elderly but decreased pleasantness for the young [d.f. = 1, $X^2 = 6.65$, $p< 0.01$].

### *Olfactory sensitivity & responsiveness to compensation*

The young outperformed the elderly in olfactory sensitivity [$F\ (1, 105) = 44.581$, $P < 0.001$]. The mean scores for detection were 12.8 (± 3.28 S.D.) and 15.5 (± 0.77 S.D.), and for identification 9.4 (± 3.54 S.D.) and 13.1 (± 2.08 S.D.) resulting in cumulative scores of 22.2 and 28.6 for the elderly and young respectively. Dividing the elderly into three groups according to their olfactory sensitivity revealed a significant difference in responsiveness to the flavor enhancement in the custard dessert [$F\ (4, 98) = 2.740$, $P < 0.033$]. Only the elderly in the "high" subgroup (CS 27-32) liked the low flavor enhancement (Figure 2).

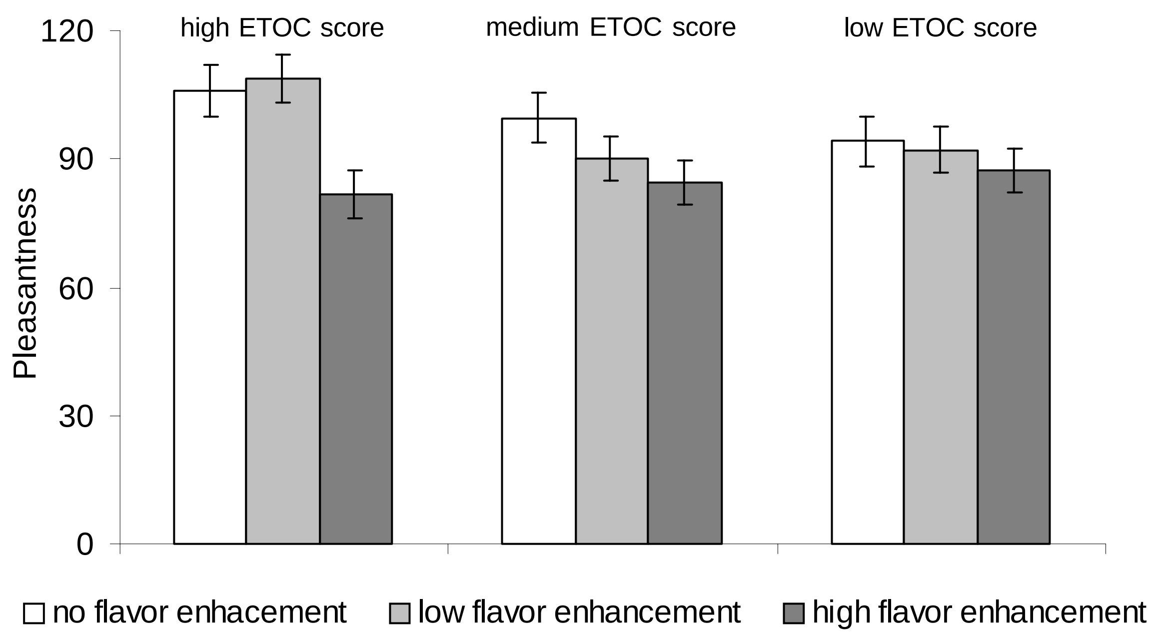


*Figure 2. Mean pleasantness ratings (±SEM) in custard desserts with no, low and high flavor enhancement by the elderly split into olfactory sensitivity groups according to their performance in the ETOC.*

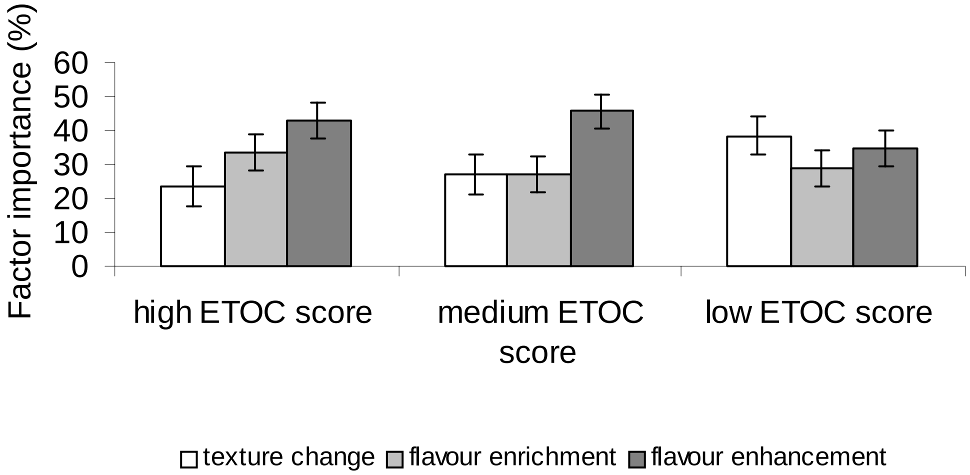


*Figure 3. Mean factor importance (±SEM) of the elderly split into olfactory sensitivity groups according to their performance in the ETOC.*

It also revealed a significant difference in the contribution of texture change to pleasantness of the custard desserts [$F$ (2, 49) = 3.179, $P$ <0.049]. Changing the texture was more influential to pleasantness in the "low" olfactory sensitivity group (CS 0-20) than in the two other groups (Figure 3). For the health drinks, neither a difference in responsiveness nor a difference in factor importance could be observed among the 3 olfactory sensitivity subgroups.

# Discussion

The pleasantness ratings were analyzed in two ways in the present study. Firstly, the parametric analysis of variance and secondly the multivariate conjoint analysis, based on the ranked rating scores. Looking at the results, there is quite some agreement between the two ways of analyzing the data with respect to the effect of age and the influence of compensatory strategies on pleasantness, but not on all points. Whereas analysis of variance did not reveal a significant age effect on pleasantness by flavor enrichment or flavor enhancement of custard desserts, conjoint analysis did. For the majority of elderly, the addition of low cherry flavor and/or low cream flavor had a positive influence on pleasantness. This clearly demonstrates a fallacy that is often encountered in hedonic studies: as liking for very specific product characteristics can be idiosyncratic, a large amount of information about the consumer response is lost through looking only at the groups' averages (Köster, 2003). Hence, conjoint analysis seems to be very useful as an additional statistical tool, since it provides extra information in form of part-worth estimates on individual hedonic consumer responses.

Since the pleasantness ratings mostly decreased by adding cream flavor to the custard desserts, the authors acknowledge that the cream flavor mixture used in the present study might not have been the optimal choice for increasing the perceived creaminess of the custard desserts.
According to the ANOVA results in the present study, neither flavor enhancements nor flavor enrichment increased the product liking of the elderly. However, looking at the frequencies of positive part-worth estimates, low flavor enrichment and low flavor enhancement influenced positively the pleasantness of custard desserts for the majority of the elderly. Flavor enhancement or enrichment may increase the product liking of elderly people (Schiffman & Warwick, 1993; Griep et al., 1997; Griep et al., 2000, Schiffman, 2000), although this is not inevitable (Koskinen et al., 2003b; Mojet et al., 2005; Kremer et al., 2005, Kremer et al. in press). The contradiction in these findings might have several causes. Firstly, all studies used different food systems, thus results derived from one food system may not be relevant for other food systems. Secondly, different flavor concentrations were used. In the present study, the success of extra flavor addition depended on whether or not an adequate flavor concentration was used i.e. whether or not the perceived intensity of the flavor fell above or below the "optimal point" of the hedonic function. Finally, the elderly population samples tend to vary in health status and sensory capabilities (Thomas-Danguin et al., 2003; Koskinen et al., 2003a). Results derived from frail nursing home residents (Griep et al., 1997) may not be relevant to healthy, community-dwelling elderly and vice versa. The limited number of subjects in some of the studies further complicates a direct comparison (Griep et al., 1997, Mojet et al., 2005; Kremer et al., 2005). In conclusion, flavor enhancement/enhancement will not generally increase food liking for all elderly in all products. While some elderly might consider an increase in flavor as an improvement, others might experience it as an overpowering change. Further research is needed to reveal whether or not it is possible to identify first specific subgroups in the diverse elderly consumer segment and then to specially target them with flavor-enhanced products.
The elderly equally liked the drinks with no or with-low irritant addition, whereas the young generally disliked an irritant addition. However, the addition of irritant did not increase the pleasantness for the elderly. The most plausible explanation for this finding is that a slightly decreased sensitivity of the elderly to irritation (Frasnelli & Hummel, 2003) made them more tolerant than the young to a low-level irritant addition. Some elderly expressed a strong liking for chemical irritation (Forde & Delahunty, 2002; Forde & Delahunty, 2004) but the increased irritant sensation seemed unlikely to compensate for sensory losses, even more so, since in the present study a similar observation was

made for both the elderly and the young. Irritation, in contrast to other sensations in foods, is either strongly liked or strongly disliked (Prescott & Stevenson, 1995), so it should come as no surprise that there are some elderly that really like irritation. Since a general trend of increased liking for irritation has not been demonstrated in the elderly, it seems unlikely that irritant addition will be practical in product development particularly as irritation sensitivity varies widely (Cliff & Green, 1996).

Although the addition of cream topping proved to improve product characteristics for both the elderly and the young, it seems not advisable to draw any conclusions from it with respect to changing texture as a compensatory strategy. Interestingly, for a clear majority of the young, the addition of a high amount of cream topping had a positive influence on pleasantness, whereas some of the elderly appreciated whilst others disapproved of this textural change. This confirms an earlier finding by Kälviäinen et al. (2003) that, provided that the ease-of-eating criterion is fulfilled, the elderly are more diverse in their texture likes than the young. This result merits further investigation in a range of other foods textures, since it might aid in the development of improved carriers for nutritional supplements, which are used to counteract the "anorexia of aging" syndrome in nursing homes and hospitals.

It was hypothesized by Mojet et al. (2005) that consumers may be guided by product concepts of familiar products in judging pleasantness and that ageing seems to have no or only very little influence on this mental image. This hypothesis is supported by several findings. Firstly, in studies in which elderly consumers encountered a product that is novel to them, they differed in their pleasantness from the young (Forde & Delahunty, 2002; Koskinen et al. 2003a; Forde & Delahunty, 2004). Secondly, elderly and young consumers demonstrated similar flavor preferences for traditional waffle types but different preferences for novel waffle types (Kremer et al. in press). In the novel waffles, the elderly preferred the flavor-enhanced variants. At first sight, the present study does not support the hypothesis as the elderly demonstrated different preferences than the young for both the "well-known" custard desserts and the "novel" health drinks. However, the custard desserts might have been considered novel as its custard powder base is only available commercially in Germany and the combination of cherry flavor and cream flavor is rarely encountered in Dutch custard desserts.

The notion that food appreciation in elderly shifts from one dominant factor to another was not confirmed by the present study except for those elderly with low ETOC scores. For them, the texture change was more influential and the flavor enrichment/enhancement was less influential in custards but this was not observed for the health drinks. Thus, it seems that the attention shift in food appreciation from one dominant factor to

another may not only be product dependent but may also be related to decreased olfactory sensitivity of the subjects rather than to their actual age.
The age differences in olfactory sensitivity measured by the ETOC in the present study are in line with recent publications (Thomas-Danguin et al., 2003; Koskinen et al., 2003b; Koskinen & Tuorila, 2005, Kremer et al., in press). Over the last decade it was frequently hypothesized that the elderly prefer flavor enhanced food, because it compensates for their assumed diminished olfactory capabilities, although the actual olfactory sensitivity of the subjects was measured in none of the earlier studies (Schiffman & Warwick, 1993; Griep et al., 1997; Griep et al., 2000). Interestingly, in studies in which the olfactory sensitivity was assessed, there was no direct connection between poor olfactory performance and preference for flavor-enhanced foods (Koskinen et al., 2003b; Issanchou, 2004; Forde & Delahunty, 2004; Kremer et al. in press). From the present results there was no indication that the elderly in the "medium or low" olfactory sensitivity groups preferred flavor-enhanced foods. In contrast, only elderly with similar olfactory acuity to the young demonstrated a liking of low flavor enhancement. This result suggests that flavor enhancement has very limited power to increase food liking for olfactory impaired elderly and that age associated olfactory losses do not inevitably lead to a preference for flavor-enhanced foods.
In summary, very limited support is found for the assumption that compensatory strategies are beneficial in increasing food liking for the elderly in general. Nonetheless, for each compensatory strategy, subgroups were observed in which applied compensatory strategies led to an increase in product pleasantness. Therefore, it seems that compensatory strategies will only be beneficial to increase elderly food liking when they can be targeted at specific subgroups of the elderly. Further research is needed for identification of these subgroups; especially as age-associated losses in olfactory capabilities do not relate strongly to preference.

## Acknowledgements

The authors thank Nancy Holthuysen and Mariska Nijenhuis for their assistance in preparing and conducting the experiments and Dr. Eric Dransfield for his valuable comments. This work is a part of the "HealthSense" project (Healthy Ageing: How Changes in Sensory Physiology, Sensory Psychology and Sociocognitve Factors Influence Food Choice) and was carried out with financial support from the EU, Fifth Framework Programme 1998-2002 (QLK1-CT-1999-00010).

# Chapter 5

## Intensity discrimination with age

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Chemical Senses, submitted as pre-test together with chapter 6

# Abstract

Just noticeable differences (JNDs) - the amount of change in physical stimuli necessary to produce a perceptible difference in sensation - were determined in custard desserts for both elderly (n = 24, 61-86 years) and young (n = 24, 18-24 years) subjects. The elderly required a larger stimulus increase in order to experience the same difference as the young. With respect to the experiment described in chapter 6 it was recommended to apply sufficiently large steps in cherry flavor and thickener concentration to ensure that not only the young but also the elderly perceive differences in the flavor and texture of the custards.


# Introduction

A just noticeable difference (JND) is the amount of change in a physical stimulus necessary to produce a perceptible difference in sensation. The determination of JNDs in food products for both elderly and young subjects yields extra information on their sensory sensitivity, since it is a measure of their discriminatory abilities above the recognition threshold. The experiment had the following objectives. Firstly, it served to determine the thickener, flavor and trigeminal concentrations to be used in the experiment described in chapter 6 and secondly to indicate whether or not the elderly required a larger increase in stimulus concentration in order to experience a difference than the young.

# Materials and methods

## *Subjects*

A group of elderly (n = 24, mean age 67, range 61-86 years) and young (n = 24, mean age 21, range 18-24 years) subjects, taken from larger groups from the experiment described in chapter 6, participated in the present study. More detailed information on the subjects can be found in the material and method section of chapter 6.

## *Stimuli*

Custard desserts (Paradies Crème, Dr. Oetker KG, Bielefeld, Germany) were used in this study together with different concentrations of the cherry flavor (Ducros, Avignon, France) of the thickener (Simplesse® / Microparticulated whey protein concentrate; Brenntag Specialities B.V., Loosdrecht, the Netherlands) or of the oral irritant (capsaicin, 60% pure solution from the Spanish pepper Capsicum annum, IFF B.V., Hilversum, the Netherlands). In a pilot test a flavor concentration was established by paired comparisons that was significantly perceived as cherry flavor in the custards (n = 10, mean age 64, range 61-79 years). This concentration (600 μl cherry flavor per 300ml full fat milk and 70g custard powder) was then chosen as the standard for cherry flavor in the flavor discrimination task. Five comparison stimuli were prepared for this standard, all being more concentrated than the standard (1.5 %, 2.3 %, 3.4 %, 5.1%, 7.6 %). Similarly, a thickener concentration was established for 9 of the elderly (mean age 63, range 61-77 years) that significantly increased the thickness of the custards compared to the custard without any extra thickener addition. This concentration (4g of thickener per 300ml full fat milk and 70g custard powder) was then chosen as the standard for thickness in the thickness discrimination task. Six comparison stimuli were prepared for this standard, all being more concentrated than the standard (1.4 %, 2.0 %, 2.7 %, 3.8 %, 5.4%, 7.5 %). Similarly, a capsaicin concentration was established for 10 elderly (mean age 66, range 63-82 years) that was significantly perceived as prickling in the custards. This concentration (3 μl of capsaicin solution per 300ml full fat milk and 70g custard powder) was then chosen as the standard for prickling in the irritant discrimination task. Four comparison stimuli were prepared for this standard, all being more concentrated than the standard (1.1 %, 1.2 %, 1.6%, 1.8%).

### Procedure

The JNDs were established with the method of constant stimuli. In each trial, two standard stimuli were assessed together with a comparison stimulus by means of a three-stimulus test. The comparison stimuli were presented in random order. In total, each subject assessed 5 triads in the flavor discrimination task, 6 triads in the thickeness discrimination task and 4 triads in the irritant discrimination task.

### Data analysis

The proportion (P) representing the number of times the comparison stimulus was identified correctly was calculated for each of the five/six/four levels of comparison. The proportions were corrected for chance (P corr) and corresponding z-scores were calculated. We defined the JND as the ratio of two stimulus concentrations that results in a z-score of zero (= 50% correct discrimination). Therefore, the difference between the standard concentration and the x-intercept of the linear function *z(P corr) = log([Stimulus]/[Standard])* is our estimate for the JND. The Weber ratio (Wr) was determined as the ratio between the JND value and the standard concentration value.

# Results

Figure 1a shows the fitted straight lines for the elderly ($Y = 1.57x - 0.81$, $R^2 = 0.94$) and the young ($Y = 1.91x - 0.68$, $R^2 = 0.97$) in the flavor discrimination test. For the elderly one JND equaled a $10^{0.515}$ or 3.27-fold (=Weber ratio) increase in added flavor concentration, whereas for the young one JND equaled a $10^{0.354}$ or 2.26-fold increase in flavor.
Figure 1b shows the fitted straight lines for the elderly ($Y = 3.35x - 1.82$, $R^2 = 0.93$) and the young ($Y = 5.0x - 1.60$, $R^2 = 0.97$) in the texture discrimination test. For the elderly one JND equaled a $10^{0.541}$ or 3.48-fold (=Weber ratio) increase in added thickener concentration, whereas for the young one JND equaled a $10^{0.320}$ or 2.09-fold increase in thickener.
Figure 1c shows the fitted straight lines for the elderly ($Y = 7.0x - 1.86$, $R^2 = 0.97$) and the young ($Y = 10.96x - 2.79$, $R^2 = 0.99$) in the irritant discrimination test. For both the elderly and the young 50% correct discrimination was not even achieved for the highest concentration difference whereas at the same time the subjects already described the prickling intensity as extremely intense.

# Discussion

In the present study, the elderly required a larger increase in flavor and thickener concentration in order to experience the same difference as the young. This finding agrees with several other studies. Firstly, the young outperformed the elderly in intensity discrimination of NaCl dissolved in tomato soup (Stevens et al. 1991). Secondly, aging was found to be associated with larger Weber ratios in aqueous solutions of caffeine but not for sucrose (Gilmore & Murphy, 1989). Thirdly, Schiffman (1993) reported that the elderly required a concentration increase of 25% in NaCl, KCl and CaCl2 dissolved in aqueous solutions to perceive a difference in intensity, whereas the young needed only a 6-12% increase. Finally, in vision and audition/sound the elderly are also reported to require larger contrasts to discriminate between stimuli (Crassini et al., 1988; Andreasen 1980; Olsho et al., 1985). In contrast to these observations, Mojet et al. (2003) reported that taste intensity discrimination of the elderly was remarkably resistant to the effect of aging, measured both in aqueous solution and in food products.
An estimate of irritant JND has not been obtained with the present method, since the sensitization properties of capsaicin (Prescott, 1999) interfered with the assessment of concentration difference by means of triangle tests. We took no further attempts to establish the just noticeable difference for capsaicin, since the higher capsaicin concentrations used in this experiment were already reported to be highly unpleasant. There-

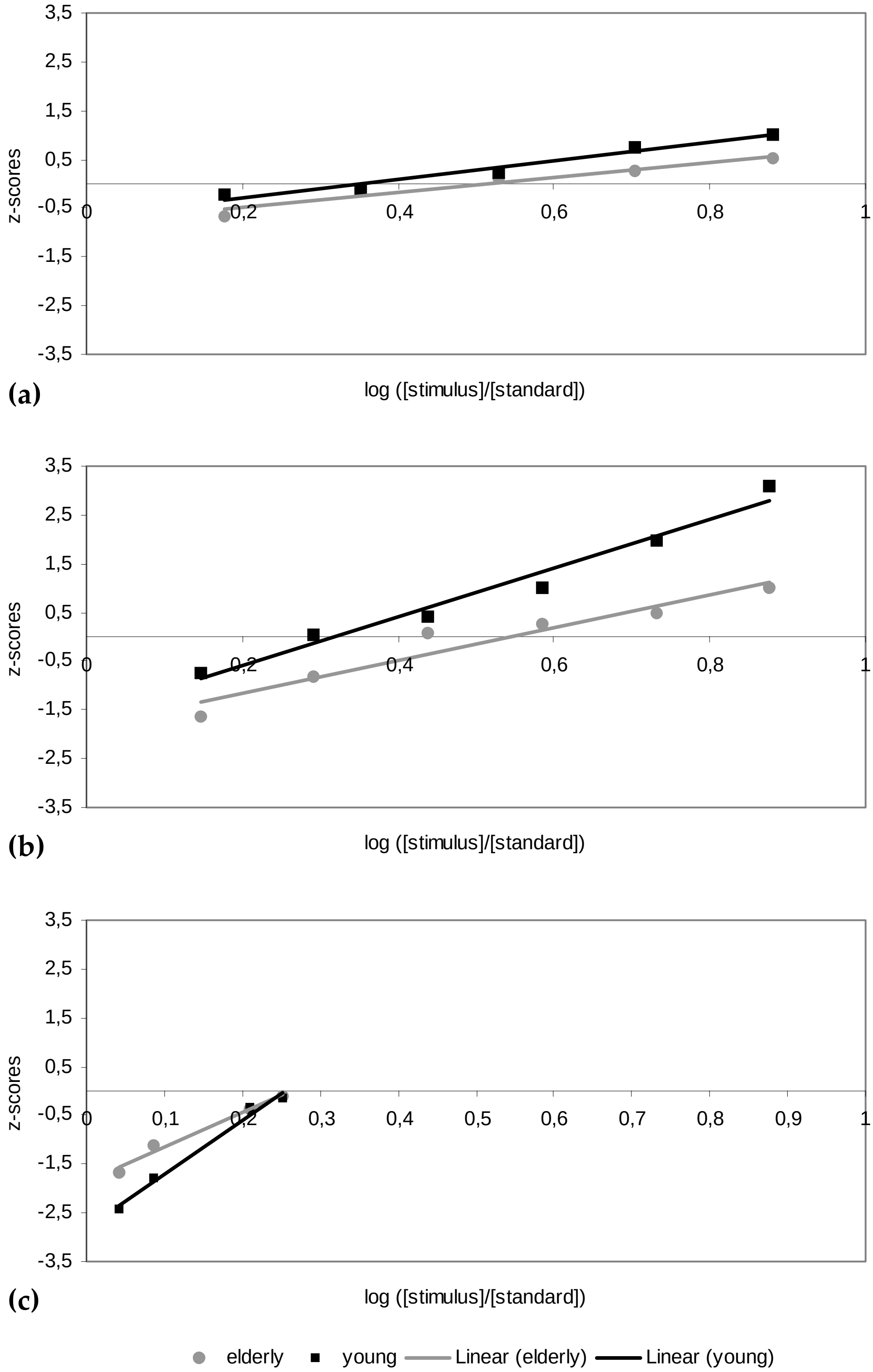


*Figure 1. Plot of z-scores for correct discrimination of the elderly and the young subjects against the logarithm of stimulus concentration for a) flavor, b) texture and c) irritation.*

fore, the capsaicin concentrations used in the experiment described in chapter 6 were estimated from the results of the pilot paired comparison tests.

In the present study, the observed impairment of the elderly in texture and flavor discrimination tasks might originate from age-induced changes in sensory performance, that have been reported to affect more or less all of the sensory modalities. For example, neuronal responses of the elderly generally slow down accompanied by an increase in stimulus persistence (Salthouse, 1996) and this might be accompanied by an increased persistence of the stimulus in the neural representation (Raz et al. 1990). As a result, the neural representation of stimuli arriving in sequence might overlap to the extent that differences might become blurred. Furthermore, it is more difficult for the elderly to divide attention between various sensory inputs or stimuli (Craik & Simon, 1980). Thus, irrelevant information processed in conjunction with stimulus information might inhibit the discrimination processes of the elderly.

## Conclusions

In the experiment described in chapter 6 we are interested in possible age-associated differences in interaction effects between the different senses. Therefore, it seemed recommendable to apply sufficiently large steps in cherry flavor and thickener concentration to ensure that the elderly perceive differences in the flavor and texture of the custards. The flavor and thickener concentration levels chosen for the experiment described in chapter 6 were levels at which 75% of the elderly were able to discriminate in this test.

# Chapter 6

## Food perception with age and its relationship to pleasantness

Stefanie Kremer, Johannes H.F. Bult, Jos Mojet and Jan H.A. Kroeze

Chemical Senses, submitted

## Abstract

Differences between elderly subjects (n = 46, 61-86 years) and young subjects (n = 36, 18-25 years) in sensory acuity, food perception and food liking were investigated. Intensity and liking ratings for the same elderly and young were assessed for custard dessert, in which flavour enrichment, textural change and irritant addition were incorporated. Different sensory acuity tests were included (taste, olfaction, irritation, chewing efficiency) and the influence of demographic factors, food habits and oral health on perception and liking of the elderly was measured. The young outperformed the elderly in the sensory acuity tests. Several observed interaction effects were different for the elderly and the young. The majority of these differences manifested as lower intensity slopes for the elderly. Subgroups of the elderly were observed in which applied compensatory strategies led to an increase in food liking. However, these subgroups did not differ in their sensory acuity. The present study does not support the assumption that age-associated changes in perception - caused by a differential decline in sensory acuity - will affect the integrated product concepts of the elderly to an extent that this will inevitably lead to changes in their food liking.

## Introduction

Although ageing is accompanied by a decreased efficiency in sensory processing in general (Corso, 1981), this decrease may not be uniform in all senses. For example, olfaction is more affected than taste (Stevens et al. 1984). Similarly, it has been reported that age-associated decline in sensitivity is more pronounced for olfaction than for nasal irritation (Hummel et al. 1998) and is larger for taste than for oral somatic sensations when determined as thresholds (Fukunaga, et al. 2005). Furthermore, there is also a greater variability in sensory acuity within a group of elderly subjects than within a group of young subjects. While some elderly clearly demonstrate impairments in their sensory performance, others maintain performance levels similar to those of younger age groups (Calhoun et al., 1992; Koskinen et al., 2003a; Thomas-Danguin, T. et al., 2003).

While eating or drinking, individuals experience a multi-faceted combination of sensations, which are integrated into one "gestalt". By mere exposure, this "gestalt" will become an internal prototype i.e. integrated product concept. It seems likely that differential declines in sensory acuity with age might cause changes in this cross-modal integration of sensory information. Only a few authors have investigated whether or not sensory interactions change with age. In two studies on orthonasal smell-taste interactions no age effect was found (Hornung & Enns 1984, Enns & Hornung 1988). In two recent studies elderly and young subjects differed in their texture - flavor interaction effects for soups but not for waffles (Kremer et al., 2005, Kremer et al., 2006). So, it seems too early to draw general conclusions as the extent of interaction may also be influenced by the type of product and/or ingredients (Pangborn et al., 1978).

Compensatory strategies, such as adding or increasing certain ingredients (e.g. flavors or irritants) or changing food texture, aim to compensate for age-associated losses in sensory acuity. It is assumed that these sensory losses with age translate into modifications of food pleasantness and food choice, although data in support of this assumption are currently lacking (see review of Mattes, 2002). In addition, very limited support was found recently for the assumption that compensatory strategies are effective in increasing food pleasantness for all elderly (Kremer et al., submitted). Only subgroups of elderly were observed, in which applied compensatory strategies - such as flavor enhancement or irritant addition - seemed to be effective. Interestingly these subgroups did not differ in their olfactory acuity.

The present study investigates whether or not elderly and young differ in their food perception and food liking. Attribute intensities and pleasantness were both assessed in custard desserts, in which flavor enrichment, textural change and irritant addition were incorporated to compensate for sensory losses. Different sensitivity tests were included as subjects with poor sensory acuity may differ in their integrated product concepts and respond differently to compensatory strategies than those with normal sensory acuity. In addition, the influence of demographic factors and/or oral health on product perception and pleasantness of the elderly were studied.

# Materials and methods

## *Subjects*

Initially, a total of 48 young and 48 elderly subjects were recruited. 2 of the elderly were unable to complete all experimental sessions as compared to 12 of the young subjects. As a consequence, their results were excluded from the data analysis. The elderly (33 females and 13 males, mean age 71, range 61-86 years) lived independently either in the area of Zeist or of Wageningen, the Netherlands, and they prepared their daily meals themselves. They were recruited by advertisements in local newspapers. The elderly were screened for cognitive impairment by the translated mini-mental state test (Folstein et al., 1975) and they were only accepted into the panel with a 100% correct score. This was done to avoid a study bias caused by diminished cognitive abilities due to neurodegenerative disorders such as dementia or Alzheimer. The young subjects (24 females and 12 males, mean age 22, range 18-25 years) were students of Wageningen University or members of a sports club in Ede, the Netherlands. The subjects participated in four tasting sessions lasting approximately 60 min each and received a fee for participation at the completion of the test.

### Samples

The same custard desserts as in chapter 5 were used in the present experiment. For one batch, 70 g of custard powder (Paradies Crème, Dr. Oetker KG, Bielefeld, Germany) was mixed with 300 ml full fat milk and three additional ingredients of 1 of 3 levels according to a 3x3x3 full factorial design. Texture was changed by adding zero, low [4 g] and high [22.2 g] amounts of thickener (Simplesse® / Microparticulated whey protein concentrate; Brenntag Specialities B.V., Loosdrecht, the Netherlands). Flavor enrichment was achieved by adding zero, low [600 µl] and high [5220 µl] amounts of cherry flavor (Ducros, Avignon, France) and irritant addition by adding zero, low [1.5 µl] and high [4.5 µl] amounts of capsaicin (60% pure solution from the Spanish pepper *Capsicum annum*, IFF B.V., Hilversum, the Netherlands).
All samples were prepared at least 18 hours before serving, were placed in 50ml plastic cups with lids and stored overnight in a food grade chill room at 4°C. Two hours before serving, all samples were taken out of the chill room and they were served at room temperature (21 ± 2 °C).

### Procedure

The tasting sessions for the young subjects were held in meeting rooms of Wageningen University, and sessions for the elderly were held in clubrooms of the service centers in Zeist and Wageningen. Tests were conducted once a week from 10-12 am over a period of five weeks. The subjects received randomized sub-sets of the 27 custard desserts during the first three sessions and participated in different sensitivity tests during the last two sessions. Per sample, pleasantness was always assessed first on a 100 mm horizontal visual analogue scale. Next, the intensities of the sensory attributes thickness (THI), creaminess (CRE), swallowing effort (SEF), vanilla flavor (VAN), cherry flavor (CHE), sweetness (SWE) and oral prickling (PRI) were rated on visual analogue scales. The verbal anchors were Dutch terms that translate to "very little/weak" and "very much/strong" and were placed at 10% and 90% of the scale respectively. The samples were coded with random three-digit numbers and were presented in random order per person. The same randomization scheme was used for the two age groups. Panelists were instructed to rinse with water and to eat cream crackers between the samples. The inter-stimulus interval was 2 min. After the five-weeks test cycle, the elderly panelists completed a demographic questionnaire.

## Sensory acuity

The sensitivity tests used in the present study were especially developed within the EU-funded HealthSense project to assess the sensory acuity of elderly subjects.

### Taste sensitivity test

Taste acuity was assessed using aqueous solutions of stimuli of four concentrations of the taste qualities sweet (sucrose: 1.1, 3.5, 10.9 and 34.6 g/l), sour (citric acid: 0.13, 0.26, 0.53 and 1.1 g/l), salty (NaCl: 0.19, 0.59, 1.9 and 5.9 g/l), and bitter (quinine: 1.84 x $10^{-3}$, 3.97 x $10^{-3}$, 8.55 x $10^{-3}$ and 1.84 x $10^{-2}$ g/l) (Johansson, Hall & Bengtzon, submitted). The taste solutions were presented at room temperature in 10-ml portions in 150-ml disposable plastic cups. The sip-and-spit method was used and the subjects were asked to identify the taste. For each correct taste identification one point was given, resulting in possible scores ranging from 0-16.

### Olfactory sensitivity test

The European test of olfactory capabilities  (ETOC) was used to measure the olfactory performance in the final session (Thomas-Danguin et al., 2003). Sixteen food and non-food odors were presented in 16 sets. Each set consisted of 1 odor-filled vial and 3 empty vials. The subjects indicated which of the 4 vials contained an odor (detection) and then, they selected one from a list of four descriptors (identification). For each correct odor detection one point was given. Only when the odor was identified correctly was another point given for correct identification. This gave scores ranging from 0-32.

### Trigeminal sensitivity test

The trigeminal sensitivity test (Lähteenmäki, Katina, Issachnou & Gourillon, 2001) involved compounds representing different trigeminal sensations: oral astringency (tannic acid: 5.0 x $10^{-4}$, 2.0 x $10^{-3}$, 8.0 x $10^{-3}$ and 3.2 x $10^{-2}$ g/l), oral cooling (menthol: 5.2 x $10^{-5}$, 2.1 x $10^{-4}$, 8.3 x $10^{-4}$ and 3.3 x $10^{-3}$ g/l), nasal burn (ammonia: 2.0 x $10^{-3}$, 8.0 x $10^{-3}$, 3.2 x $10^{-2}$ and 12.8 x $10^{-2}$ g/l) and oral burn (piperine: 2.0 x $10^{-4}$, 6.0 x $10^{-4}$, 2.4 x $10^{-3}$ and 9.6 x $10^{-3}$ g/l). The aqueous solutions were served at room temperature in 150-ml disposable cups filled with 10-ml of the solutions. The solutions of tannic acid, menthol and piperine had to be tasted while the solutions of ammonia had to be smelled only. Since the oral trigeminal effect was to be tested, the subjects had to wear a nose clip (except for ammonia) to block the olfactory input. The sip-and-spit method was used. The panelists received set of pairs of samples for paired comparison (blank + stimulus), starting with the lowest concentration. The solutions were assessed according to the ascending 2 AFC-two in a row method. The sensitivity level was defined as the concentration at which two correct answers in a row from the same concentration were achieved. The possible range of sensitivity levels varied from 1 to 5, where 1 represented the highest sensitivity and 5 the lowest sensitivity.

#### *Chewing efficiency test*

Chewing efficiency was measured using two-coloured chewing gum (Bang Bang cola-lime, Joyco Group, Spain). It was chewed 20 times and than spit out. The degree of mixing was later compared by three independent judges to a standard picture scale ranging from score 0 (no mixing) to 8 (fully mixed) (Fillion & Kilcast, 2001). The average of the three judgments was taken; the deviation between the three judges was never larger then two steps.

### *Demographic questionnaire*

Further insight into the background of the elderly was gained by a demographic questionnaire in which the elderly answered questions with regard to their education level, living conditions, food habits, and oral health.

### *Data analysis*

Main effects of age (Age), added thickener (Texture), added cherry flavor (Flavor) and added capsaicin (Irritation) and their interaction effects with age on attribute intensity and pleasantness were tested by univariate repeated measures analysis of variance (ANOVA) with age as between-subjects factor and texture, flavor and irritation as within-subjects factors. To correct the model for deviations of sphericity, the degrees of freedom were adjusted with the Huynh-Feldt epsilon, if necessary. Post hoc tests were performed using the least-significant difference (LSD) method. The analyses of variance were performed using SPSS v. 11.0 (SPSS Inc. Chicago, IL 60611, USA).
Conjoint analysis was conducted on pleasantness ratings ranked per person (Hair et al., 1998). For each age group, the factor importances for each individual were computed and averaged. In addition, within each experimental factor, the influence of the different concentration levels on the pleasantness ratings were determined as part-worth estimates, e.g. a factor level with a positive part-worth estimate will have influenced the pleasantness ratings positively and the contrary (Hair et al., 1998). The frequencies of +/0/- part worth estimates were collected and possible differences between the two age groups were tested by means of chi-square analysis.

The data of the different sensitivity tests were analyzed with a one-way analysis of variance. Next, the elderly were divided into three subgroups based on their scores in the different sensitivity tests using the 33.3 and 66.6 percentile as a cut-off point. The effect of sensitivity on the attribute and pleasantness ratings were tested by univariate repeated measures analysis of variance (ANOVA) with sensitivity as between-subjects factor and the experimentally manipulated factors as within-subjects factors.

# Results

## *Age & intensity ratings*

The elderly produced lower scores than the young on 4 out of 7 sensory attributes: creaminess [$F$ (1,80) = 10.153, $P$ = 0.002], swallowing effort [$F$ (1,80) = 29.476, $P$ =0.001], vanilla flavor [$F$ (1,80) = 5.470, $P$ = 0.022] and cherry flavor [$F$ (1,80) = 66.096, $P$ =0.001] (Fig. 1). No significant main age effect was observed for thickness, sweetness and prickling.

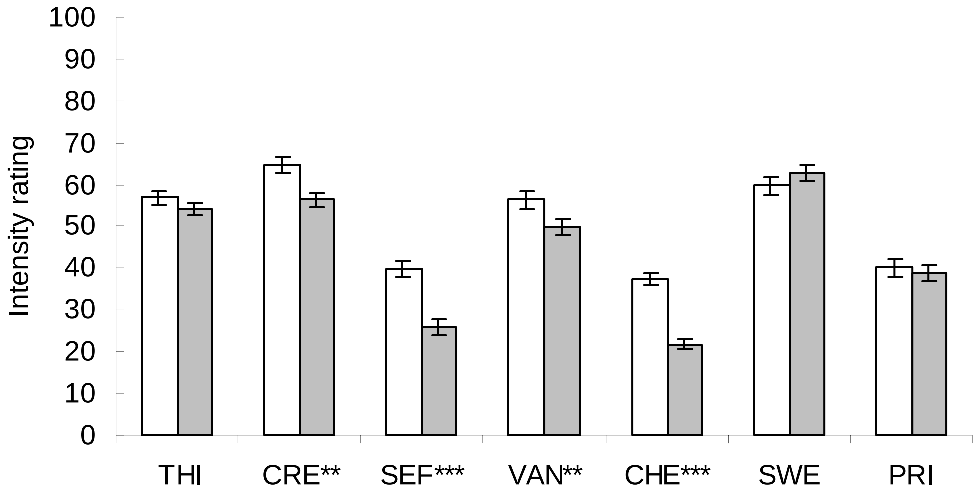


*Figure 1. Mean intensity ratings (±SEM) of thickness (THI), creaminess (CRE), swallowing effort (SEF), vanilla flavor (VAN), cherry flavor (CHE), sweetness (SWE) and prickling (PRI) in custard desserts by the elderly (filled bars) and the young (unfilled bars). *p <= 0.05, **p <= 0.01, ***p <= 0.001.*

The F- and P-values of interaction effects between age and perception or pleasantness are reported in Table 1. In the majority of the observed interaction effects, the addition of three different concentrations of thickener, cherry flavor or capsaicin induced significant changes in perceived intensities for the young but not, or to a significantly lesser extent, for the elderly.

*Table 1. Influence of added thickener, added flavor and added irritant on sensory attributes perceived by elderly and young. * P <= 0.05 ** P <= 0.01 *** P <= 0.001.*

| Attribute | df 2,160 | | Thickener | | | Flavor | | | Irritant | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | zero | low | high | zero | low | high | zero | low | high |
| Thickness | | F-value | | 85.55*** | | | 11.22*** | | | N.S. | |
| | Young | mean | 46.3 | 54.4 | 70.0 | 59.1 | 58.7 | 52.8 | 56.3 | 57.0 | 57.3 |
| | Elderly | mean | 51.7 | 51.6 | 56.0 | 53.6 | 52.7 | 53.1 | 52.5 | 53.6 | 53.3 |
| Creaminess | | F-value | | 24.67*** | | | N.S. | | | N.S. | |
| | Young | mean | 57.3 | 63.8 | 73.2 | 65.9 | 66.4 | 62.0 | 63.9 | 65.1 | 65.3 |
| | Elderly | mean | 54.7 | 56.9 | 57.2 | 55.6 | 57.9 | 55.4 | 57.0 | 56.2 | 55.7 |
| Swallowing effort | | F-value | | 34.17*** | | | 7.58** | | | N.S. | |
| | Young | mean | 33.3 | 37.3 | 48.9 | 41.0 | 41.3 | 37.2 | 40.2 | 40.1 | 39.2 |
| | Elderly | mean | 25.0 | 25.7 | 26.9 | 26.9 | 25.1 | 25.6 | 25.8 | 25.3 | 26.5 |
| Vanilla flavor | | F-value | | 9.90*** | | | 32.62*** | | | N.S. | |
| | Young | mean | 54.3 | 55.0 | 60.0 | 64.5 | 61.7 | 42.8 | 54.9 | 58.2 | 56.0 |
| | Elderly | mean | 50.5 | 50.4 | 48.7 | 51.6 | 51.4 | 46.6 | 50.1 | 49.8 | 49.7 |
| Cherry flavor | | F-value | | 10.03*** | | | 102.89*** | | | N.S. | |
| | Young | mean | 38.6 | 38.8 | 34.0 | 22.9 | 28.7 | 59.9 | 38.0 | 37.1 | 36.3 |
| | Elderly | mean | 22.4 | 21.1 | 21.5 | 18.9 | 19.9 | 26.2 | 21.9 | 22.1 | 21.1 |
| Sweetness | | F-value | | N.S. | | | N.S. | | | N.S. | |
| | Young | mean | 59.4 | 59.5 | 60.0 | 59.3 | 59.8 | 60.0 | 58.2 | 62.3 | 58.5 |
| | Elderly | mean | 64.3 | 64.4 | 64.6 | 64.9 | 64.6 | 63.9 | 63.7 | 65.4 | 64.3 |
| Prickling | | F-value | | 7.23** | | | 4.15* | | | 12.01*** | |
| | Young | mean | 43.8 | 41.2 | 41.2 | 43.3 | 40.1 | 42.8 | 26.5 | 37.0 | 62.7 |
| | Elderly | mean | 37.1 | 40.1 | 38.9 | 38.4 | 39.1 | 38.6 | 26.8 | 38.1 | 51.2 |
| Pleasantness | | F-value | | N.S. | | | N.S. | | | 4.97** | |
| | Young | mean | 51.1 | 52.0 | 47.7 | 50.9 | 51.1 | 48.8 | 49.5 | 52.5 | 48.9 |
| | Elderly | mean | 52.6 | 53.0 | 51.2 | 51.4 | 53.7 | 51.7 | 54.7 | 51.4 | 50.7 |

Several complex interaction effects were observed, some involving "age" as a factor. Firstly, an age by texture by flavor interaction was found for perceived creaminess [$F$ (4, 320) = 2.720, $P$ =0.030]. The young perceived significant larger differences in creaminess

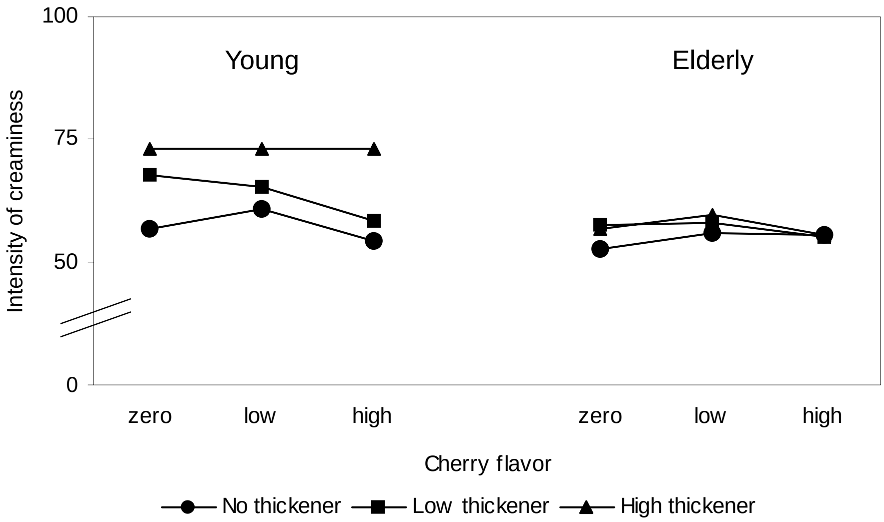


*Figure 2. Age by texture by flavor interaction for perceived creaminess in custard deserts.*

between products with different thickener and flavor concentrations than did the elderly (Figure 2).

Secondly, a texture by flavor interaction was observed for perceived vanilla flavor [$F$ (4, 320) = 6.216, $P$ =0.001]. Adding high concentrations of cherry flavor to custards with high thickener levels decreased the vanilla flavor perception to a lesser extent than when the same high cherry flavor concentration was added to custards with zero or low thickener concentration. No age difference was found for this interaction.

Thirdly, a texture by flavor by irritation interaction was found for perceived cherry flavor [$F$ (6.1, 481.4) = 2.964, $P$ =0.007]. No age difference was found for this interaction. Finally, several complex age by texture by flavor by irritation interactions were observed for thickness [$F$ (6.4, 516.3) = 3.250, $P$ =0.003], swallowing effort [$F$ (5.3, 425.7) = 5.050, $P$ =0.001] and prickling [$F$ (5.8, 468.6) = 12.892, $P$ =0.001]. Table 2 shows per product the mean intensities of thickness, swallowing effort and prickling for the elderly and the young. The elderly and young differed in their product perception in the following ways.

The three texture levels led to significant differences in perceived thickness for the young but not, or to a lesser extent, for the elderly. Compared to the zero and low flavor concentrations, the addition of high flavor concentrations decreased the perceived thickness for the young but not the elderly (for example see Table 2. products 19-21 versus 25-27). The addition of an irritant changed (decreased or increased) the perceived thickness for the young, whereas the thickness perception of the elderly was not influenced by the addition of an irritant (for example see Table 2. products 10-15). The elderly did not discriminate the products on swallowing effort, whereas the young did. In products with no or low irritant addition the addition of cherry flavor (low or high) significantly decreased the perceived swallowing effort for the young (for example see Table 2. products 10-12 versus products 16-18). In contrast to the young, the elderly were always able to differentiate between the prickling of products with no or with low irritant addition (for example see Table 2. products 16-18). The three flavor levels led to significant differences in perceived prickling for the young but not, or to a lesser extent, for the elderly. The different texture levels affected the prickling for both the young and the elderly, however, sometimes in the opposite direction (for example see Table 2. product 2 versus product 11 versus product 20).

### *Age & pleasantness*

Adding the thickener to the custard desserts decreased pleasantness [$F$ (1.67, 133.62) = 4.360, $P$ =0.020] for zero versus high addition (p = 0.007). No significant interaction effect with age was observed (Table 1). Flavor enrichment had no significant effect on pleasantness. The age by irritant interaction was significant [$F$ (2, 160) = 4.969, $P$ =0.008]. The addition of an irritant at low and high concentration both decreased pleasantness ratings for the elderly, whereas pleasantness ratings of the young were not influenced by the presence or absence of trigeminal stimulation (Table 1).

The averages of the individually calculated relative importance of the factors texture, flavor and irritation on pleasantness ratings and the frequencies of the +/-/0 part worth estimates are shown in Table 3 for the elderly and the young separately. The contributions of these factors to food pleasantness did not differ between the two age groups. All factors contributed almost equally to pleasantness.

Three significant differences in pleasantness between the two age groups were observed on the basis of the part-worth frequency estimates. Firstly, flavor enrichment at a low concentration had a positive influence on pleasantness for the majority of the elderly but for only half of the young [d.f. = 1, $X^2$ = 4.88, p< 0.05]. Secondly, no irritant addition to the custards had a positive influence on pleasantness for a majority of the elderly but for less than half the young [d.f. = 1, $X^2$ = 13.30, p< 0.001]. Thirdly, the irritant addition at a low concentration had a positive influence on pleasantness for the majority of the young but for only half of the elderly [d.f. = 1, $X^2$ = 5.83, p< 0.02].

*Table 2. Mean intensities per product of the attributes that showed a significant age by texture by flavor by irritant effect.*

| Products | Factor | | | Thickness | | Swallowing effort | | Prickling | |
|---|---|---|---|---|---|---|---|---|---|
| | Texture | Flavor | Trigeminal | Young | Elderly | Young | Elderly | Young | Elderly |
| 1 | zero | zero | zero | 45.5 | 52.9 | 32.0 | 24.7 | 25.0 | 27.0 |
| 2 | zero | zero | low | 49.2 | 50.4 | 35.3 | 25.9 | 43.6 | 35.0 |
| 3 | zero | zero | high | 49.7 | 54.1 | 34.2 | 28.0 | 71.1 | 52.4 |
| 4 | zero | low | zero | 47.2 | 48.9 | 37.5 | 26.1 | 29.7 | 25.9 |
| 5 | zero | low | low | 48.3 | 51.9 | 33.9 | 23.0 | 25.3 | 40.0 |
| 6 | zero | low | high | 46.9 | 52.2 | 36.4 | 26.1 | 74.2 | 52.2 |
| 7 | zero | high | zero | 47.5 | 52.8 | 26.7 | 22.8 | 23.9 | 27.0 |
| 8 | zero | high | low | 46.9 | 51.5 | 32.8 | 23.3 | 43.1 | 31.7 |
| 9 | zero | high | high | 45.0 | 50.4 | 31.1 | 25.0 | 58.3 | 47.4 |
| 10 | low | zero | zero | 61.7 | 48.0 | 43.9 | 29.1 | 31.1 | 24.6 |
| 11 | low | zero | low | 59.4 | 52.2 | 36.4 | 26.5 | 26.1 | 45.4 |
| 12 | low | zero | high | 50.0 | 54.4 | 36.7 | 26.1 | 74.2 | 53.9 |
| 13 | low | low | zero | 49.1 | 51.1 | 35.6 | 23.7 | 24.4 | 26.5 |
| 14 | low | low | low | 55.0 | 54.4 | 43.9 | 23.7 | 44.7 | 34.1 |
| 15 | low | low | high | 61.9 | 50.7 | 36.9 | 25.0 | 53.1 | 50.4 |
| 16 | low | high | zero | 54.7 | 49.4 | 38.3 | 25.4 | 29.4 | 29.6 |
| 17 | low | high | low | 48.6 | 53.5 | 31.9 | 25.9 | 31.4 | 44.6 |
| 18 | low | high | high | 48.7 | 51.1 | 32.2 | 25.7 | 56.1 | 52.2 |
| 19 | high | zero | zero | 73.3 | 58.7 | 48.0 | 27.0 | 20.3 | 25.2 |
| 20 | high | zero | low | 73.1 | 56.5 | 55.0 | 25.7 | 44.2 | 35.7 |
| 21 | high | zero | high | 70.3 | 54.8 | 47.5 | 28.9 | 54.4 | 51.5 |
| 22 | high | low | zero | 75.6 | 55.0 | 58.9 | 26.3 | 28.3 | 29.6 |
| 23 | high | low | low | 68.1 | 54.6 | 41.1 | 26.7 | 26.1 | 46.5 |
| 24 | high | low | high | 75.8 | 55.7 | 48.0 | 25.4 | 55.0 | 46.7 |
| 25 | high | high | zero | 62.2 | 55.9 | 40.6 | 27.2 | 26.1 | 25.9 |
| 26 | high | high | low | 64.2 | 57.2 | 50.8 | 26.7 | 48.6 | 35.0 |
| 27 | high | high | high | 67.5 | 55.9 | 50.0 | 28.5 | 68.1 | 54.1 |

*Table 3. Mean factor importance of different compensatory strategies on pleasantness of custard desserts for the young and elderly subjects. The frequency of the +/-/o part-worth estimates is cumulated. + indicates a positive part-worth estimate, - a negative part-worth estimate and o indicates no contribution.*

| | | Young (n = 36) | | | | Elderly (n = 46) | | | |
|---|---|---|---|---|---|---|---|---|---|
| Factor | Level | Part-worth estimates (frequencies) | | | Factor importance (%) | Part-worth estimates (frequencies) | | | Factor importance (%) |
| | | + | 0 | - | | + | 0 | - | |
| | Zero | 20 | 0 | 16 | | 20 | 0 | 26 | |
| Texture change | Low | 22 | 1 | 13 | 33.4 | 23 | 1 | 22 | 32.4 |
| | High | 15 | 1 | 20 | | 19 | 0 | 27 | |
| | Zero | 19 | 0 | 17 | | 20 | 2 | 24 | |
| Flavor enrichment | Low | 15 | 1 | 20 | 37.2 | 31 | 0 | 15 | 33.6 |
| | High | 15 | 0 | 21 | | 22 | 1 | 23 | |
| | Zero | 13 | 0 | 23 | | 35 | 0 | 11 | |
| Irritant addition | Low | 26 | 0 | 10 | 29.4 | 21 | 0 | 25 | 34.0 |
| | High | 15 | 0 | 21 | | 15 | 0 | 31 | |

## *Age & Sensory acuity*

The young subjects outperformed the elderly subjects in the taste sensitivity test [$F$ (1, 81) = 15.566, $P$ =0.001]. On average the young identified 12, while the elderly only identified 10 out of the 16 taste solutions. The young subjects identified a significantly larger number of the salty [$F$ (1, 81) = 8.793, $P$ =0.004] and the sour [$F$ (1, 81) = 8.287, $P$ =0.005] solutions, whereas no significant age difference was observed in the identification of sweet and bitter solutions.

The young had a higher olfactory sensitivity than the elderly [$F$ (1, 81) = 23.118, $P$ =0.001] and the inter-individual variation among the elderly was higher than among the young. For the elderly, the mean detection score was 13.72 (S.D. = 3.12) and the mean identification score 10.43 (S.D. = 3.51) resulting in a cumulative score of 24.15 (S.D. = 6.33). For the young, the mean detection score was 15.72 (S.D. = 0.57) and the mean identification score 13.64 (S.D. = 1.33) resulting in a cumulative score of 29.36 (S.D. = 1.62).

Overall, the young were significantly more sensitive to trigeminal stimulation than the elderly [$F$ (1, 81) = 4.089, $P$ =0.047] due to the fact that they were more sensitive to ammonia [$F$ (1, 81) = 5.531, $P$ =0.021] and menthol [$F$ (1, 81) = 7.217, $P$ =0.009], whereas they did not differ from the elderly in their sensitivity to piperine and tannic acid.
The chewing efficiency was reduced in the elderly [$F$ (1, 81) = 38.394, $P$ =0.001]. On average the young reached a mixing degree of 6 on a scale ranging from 0 to 8 after 20 chews, while the elderly only reached a mixing degree of 4.

### *Sensory acuity & intensity ratings*

Table 4 shows the details of the elderly sensitivity sub-groups. No significant differences in intensity responses were found when the elderly were divided in three sensitivity subgroups (high, medium, low) according to their performance in the taste sensitivity test.
Dividing the elderly in three groups according to their olfactory performance revealed a significant difference in creaminess perception in desserts with different levels of added thickener [$F$ (4, 86) = 6.25, $P$ =0.001]. Compared to the desserts with no added thickener, the addition of high amounts of the thickener decreased the perceived creaminess for the elderly in the "high" sensitivity group but increased it for both the "medium" and "low" sensitivity group.
A division of the elderly according to their trigeminal sensitivity led to the following observation. Elderly with a "high" sensitivity towards trigeminal stimuli perceived both the thickness [$F$ (2, 47) = 4.78, $P$ =0.013] and creaminess [$F$ (2, 47) = 3.37, $P$ =0.044] of the products as significantly less intense than elderly in the "low" sensitivity group.

*Table 4. Details of the elderly sensitivity subgroups.*

| | | | | Sensitivity | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 33.3% | 66.6% | Low | | Medium | | High | |
| Sensitivity tests | Range of outcome | percentile cut-off | percentile cut-off | N | Mean age (± S.D.) | N | Mean age (± S.D.) | N | Mean age (± S.D.) |
| Taste | 0-16 | ≤ 9 | ≥ 12 | 18 | 69.8 (± 5.8) | 18 | 71.0 (± 6.2) | 10 | 72.0 (± 7.5) |
| Olfaction | 0-32 | ≤ 24 | ≥ 28 | 15 | 72.7 (± 4.4) | 15 | 71.4 (± 6.2) | 16 | 68.4 (± 7.4) |
| Trigeminal | 20-4 | ≥ 12 | ≤ 9 | 15 | 69.1 (± 5.1) | 19 | 73.3 (± 6.0) | 12 | 68.8 (± 6.9) |
| Chewing efficiency | 0-8 | ≤ 3 | ≥ 5 | 17 | 72.2 (± 5.7) | 15 | 70.1 (± 6.0) | 14 | 69.6 (± 7.2) |

Dividing the elderly in three groups according to their chewing efficiency revealed a significant difference in sweetness perception. Compared to both the elderly with "high" ($p < 0.040$) or "medium" ($p < 0.003$) chewing efficiency, the elderly with "low" chewing efficiency perceived the products to be less sweet.

### *Sensory acuity & pleasantness*

Dividing the elderly into taste, olfactory, trigeminal or masticatory subgroups according to their performance in the sensitivity tests revealed no significant differences in pleasantness.

### *Demographics*

In the present study, 46% of the elderly lived alone and the remaining lived in households with two or more persons. The level of education was low for 39%, medium for 35% and high for 26 %. Of the elderly, 72% reported no change in observed food intake, whereas 22 % reported a decreased and 6% an increased food intake over the last five years. Regarding spicy foods, 39% stated that they did not like them and tried to avoid them whenever possible, 48% reported that they could tolerate spicy food up to a certain point and 13% reported that they really like spicy food. Of the elderly, 87% were none-smokers. The general health was described by 59% of the elderly as good, by 33% as fair and by 8% as bad. The oral health was reported by 61% as good, by 30% as fair and by 9% as bad. Only 35% still had their natural teeth, although some teeth were missing and 33% reported that they sometimes avoid foods due to eating difficulties.

### *Demographics & intensity ratings*

Elderly with dentures rated the custards less creamy [$F$ (1, 44) = 4.63, $P$ =0.037] and used more swallowing effort [$F$ (1, 44) = 7.6, $P$ =0.008] than elderly with natural teeth. No effect on intensity ratings was observed for household size, education level, food intake, hot food liking, oral health or eating difficulties.

### *Demographics & pleasantness*

Elderly that live alone reported the products to be significantly less pleasant than elderly that live together with two or more people [$F$ (1, 44) = 5.99, $P$ =0.018]. No effect on pleasantness ratings was observed for education level, food intake, hot food liking, oral health, dentures or eating difficulties.

### *Demographics & Sensory acuity*

The chewing efficiency was reduced in elderly subjects with dentures compared to elderly subjects with natural teeth [$F$ (1, 44) = 15.07, $P$ =0.001]. No effect on sensory acuity was observed for household size, education level, food intake, hot food liking, oral health or eating difficulties.

## Discussion

Since the present study focuses on age-associated differences in integrated perception in relation to pleasantness, both liking and attribute assessments were asked form the same subjects. To minimize a possible bias in the affective testing, pleasantness was always rated first and both the liking and the intensity assessments were made on the same scale type (see for review Popper et al., 2004).

The elderly differed from the young in their ratings of the texture attributes creaminess and swallowing effort. These findings agree with the results of previous studies on age differences in texture perception (Kremer et al., 2005; Kremer et al., 2006) in which soups were rated less creamy and waffles were rated less fat and easier to swallow by the elderly than by the young. Hence, the perception of fat-related attributes seems to be different in the two age groups. Besides the two explanations that either impaired olfaction or habituation of the elderly to higher fat levels in their past might cause these differences (Kremer et al., 2006), another explanation seems plausible. In the present study, elderly with dentures rated the custards less creamy but more difficult to swallow than elderly with natural teeth. This suggests that palatal coverage by dentures interferes with oral perception, and that differences in texture perception may be caused by denture-induced changes in chewing and mouth movements rather than by aging per se. All the more plausible is this explanation since the prime regulator of masticatory efficiency is dental integrity (Wayler et al., 1984) and the majority of the elderly in the present study had dentures and proved to be less efficient in mastication than both the elderly with natural dentition and the young.

The elderly perceived the flavor attributes (cherry/vanilla) as being less intense than the young. This finding is in line with earlier studies. The elderly required higher flavor concentrations in order to reach the same intensity rating given by the young (De Graaf et al. 1996) and they consistently gave lower flavor ratings in different foods than the young (Philipsen et al., 1995; Kremer et al., 2005; Kremer et al., 2006). The age differences in olfactory sensitivity measured by the ETOC in the present study are also in line with recent publications (Thomas-Danguin et al., 2003; Koskinen et al., 2003b; Koskinen

& Tuorila, 2005; Kremer et al., submitted): the young outperformed the elderly both in the detection and the identification task. However, no significant differences in reported flavor intensities were found when the elderly were divided into high, medium and low olfactory sensitivity groups. This finding is not in line with the previously reported lower flavor intensity ratings of the elderly with low olfactory sensitivity (Kremer et al. 2006). Together with earlier reports by Koskinen & Tuorila (2005), it raises considerable doubts as to whether or not orthonasal odor perception may serve as a reliable predictor for retronasal perception intensities in the elderly. Duffy et al. (1999) pointed out that while good olfaction may be necessary for good retronasal flavor perception, it is not sufficient. Other factors, such as chewing, mouth and/or tongue movements, dentition and oral health, were thought to influence release and retronasal transport of odors from the mouth to the olfactory receptors. Additional support for this notion comes from two studies (Burdach & Doty, 1987; De Wijk et al., 2003), in which more complex intra-oral food manipulations triggered more intense perceptions of flavor and mouthfeel attributes. Further research is needed to reveal differences in oral food manipulation by the elderly and to investigate whether or not it is possible to improve the perception of sensory attributes by encouraging the elderly to increase their intra-oral food manipulations.

In the present study, the elderly and the young did not differ in their sweetness perception neither in the intensity rating nor in the taste sensitivity test. Although this finding is consistent in itself, ambiguous results are reported in the literature. On the one hand, the elderly perceived sweet ingredients in chocolate drinks and vanilla waffles as less intense than the young (Mojet et al., 2003; Kremer et al., 2006). On the other hand, they did not differ from the young in perceived sweetness of purred fruits and vegetables or dairy products (Stevens & Lawless, 1981; Warwick & Schiffman, 1990; De Graaf et al., 1994). The present study used commercial-type semi-solid foods to study perception in the two age groups, since it has been demonstrated that supra-threshold perception of tastants dissolved in aqueous solutions is not or barely related to perception of tastants dissolved in foods (Drewnoswki et al., 1996; Mojet et al., 2003).

The elderly were always able to discriminate between products with zero and low capsaicin levels on prickling sensation, whereas the young were not. Good discriminatory ability of the elderly for capsaicin stimulation in food products has been reported earlier by Forde & Delahunty (2002). In contrast to these observations, the young outperformed the elderly in sensitivity to menthol and ammonia in the trigeminal sensitivity test. However, it is unclear whether or not the difference in performance between the two age groups is caused by a reduction in perception in the oral cavity or in olfactory sensitivity. In contrast to piperine and tannic acid, menthol and ammonia are trigeminal stimuli with a strong olfactory component.

The present study supports the hypothesis that age-associated decline in sensory acuity causes changes in perception of the elderly. Interestingly, the majority of the age differences in perception manifested as lower intensity slopes for the elderly. This finding agrees with previous observations (de Graaf et al., 1994; Mojet et al., 2003).

No general positive influence of flavor enrichment on the pleasantness of the custard desserts could be observed for the elderly, although a subgroup of the elderly responded positively to the low cherry flavor addition. Again, this demonstrates that flavor enrichment/enhancement may increase the product liking for some elderly people, but that this is not true for all elderly (Koskinen et al., 2003b; Mojet et al., 2005; Kremer et al., submitted).

The addition of an irritant at near-threshold level has been thought to provide another dimension to the eating experience of the elderly (Laska, 2001). However, the vast majority of the elderly in the present study preferred products with no irritant addition, an observation that has been made previously (Koskinen et al., 2003a; Forde & Delahunty, 2004; Kremer et al., submitted).

In the present study, no direct relationship between poor sensory performance and preference for flavor-enhanced foods was observed. This finding is in agreement with earlier reports of a lack of evidence for this relationship (Koskinen et al., 2003b; Issanchou, 2004; Forde & Delahunty, 2004; Kremer et al., 2006; Kremer et al., submitted).

In sensory and nutrition research compensatory strategies - in particular flavor enrichment/enhancement - were thought to be beneficial in increasing food liking for the elderly in general and to offer a potential cure for nutritional problems of the elderly such as "anorexia of aging" (Schiffman & Warwick, 1993; Griep et al., 1997; Mathey et al., 2001). However, in these earlier studies, poor sensory acuity of the elderly has been assumed but has not been measured. Moreover, in his review challenging old assumptions, Mattes (2002) notes that a causal relationship between age-associated sensory changes and food choice and dietary behavior has yet to be established. Furthermore, it seems unlikely that compensation will ever be practical in product development. The elderly population is known to vary considerably in health status and sensory acuity (Thomas-Danguin et al., 2003; Koskinen et al., 2003a). Thus, while some elderly might consider an applied compensatory strategy as a product improvement, others might consider it as an unnecessary and even unwelcome product change.

An interesting observation was made in the present study with respect to possible influences of non-sensory factors on the food appreciation of the elderly. Elderly that lived alone rated the products overall as less pleasant than elderly that lived in a household with two or more people. Hence, social facilitation, i.e. the amount that is eaten increases in the presence of other people (De Castro, 2002), might not only play a role as a determinant of food intake but also as a determinant of hedonic responses in general. This observation merits further research.
All in all, the results of the present study do not support the assumption that age-associated changes in perception - caused by a differential decline in sensory acuity - will affect the integrated product concepts of the elderly to an extent that this will inevitably lead to changes in their food liking. Two hypotheses may account for this missing link. Firstly, since normal deterioration of the sensory systems with age starts gradually, people may continuously habituate to their diminished perception and do not experience a decrease in food liking (Wysocki & Pelchat, 1993). Secondly, the pathways of sensory and hedonic representations do not converge in the brain and are processed by different areas in the brain (De Araujo et al., 2003; Sewards, 2004). As a result intensity perception of texture or flavor may vary between the elderly and the young, while the hedonic aspects remain essentially unchanged with increasing age.

## Conclusions

Decreased sensory acuity - although causing changes in perception of the elderly- is obviously not the predominant reason for a diminished food enjoyment of the elderly. Other non-sensory compensatory strategies that take other age-related factors into account - such as loneliness, depression, reduced social interaction - might prove to be even more successful and should be pursued in future research because elderly food enjoyment remains key to healthy ageing.

## Acknowledgments

The authors thank Nancy Holthuysen, Mariska Nijenhuis and Marjan Beetstra for their assistance in preparing and conducting the experiments and Dr. Eric Dransfield for his valuable comments on the manuscript. This work is a part of the "HealthSense" project (Healthy Ageing: How Changes in Sensory Physiology, Sensory Psychology and Sociocognitve Factors Influence Food Choice) and was carried out with financial support from the EU, Fifth Framework Programme 1998-2002 (QLK1-CT-1999-00010).

# Chapter 7

## Discussion

## Main findings

### *The elderly perceive foods differently compared to the young*

Elderly and young differ in several ways in food perception. Firstly, the perception of flavour is generally reduced for the elderly (chapter 2, 3 & 6). Secondly, the elderly and young differ in their perception of fat-related texture attributes (chapter 2, 3 & 6). Thirdly, the discrimination between different flavour/thickener concentration levels is less distinct for the elderly than for the young (chapter 5 & 6). Finally, six of the twelve observed interaction effects were different between the elderly and the young (chapter 2, 3 & 6). All these observed interaction effects seem not only to be product-type specific but also highly stimulus specific. For this reason, no general pattern can be described.

Age-related differences in food perception may originate from changes in the sensory systems of the elderly at peripheral or central level or both. They could be attributed to age-related changes in the olfactory system as mentioned in the introduction of this thesis. However, this may not be the sole factor. For example, age-related changes in mastication - caused by reduced chewing force and rate and/or dentures - will decrease the amount of olfactory volatiles that are transported retronasally to the olfactory epithelium causing diminished flavour perception which in turn will most likely affect the food perception itself (chapter 6). Furthermore, decreases in the total number of receptor cells and/or a diminished saliva/mucus production with age, which will slow down the transport of molecules to the receptor cells in the oral and nasal cavity, might generally lower the firing rates of taste, olfactory and/or somatic neurons. Finally, various noise hypotheses could be put forward to explain impairment in sensory information processing at a more central level (Essed & Eling, 1986). Decreases in neural signal intensity and/or increases in spontaneously firing neurons may lower the signal-to-noise ratio with age. Moreover, the signal-to-noise ratio may be decreased by increased stimulus persistence in the aged nervous system. In addition, it may become more difficult with increasing age to neglect irrelevant information, which would lead to an increase of noise at a psychological / perceptual level (Wright & Elias, 1979).

### *Food liking is not reduced in the elderly*

Food liking of the elderly remains remarkably stable despite changes in food perception due to diminished sensory acuity (chapter 4, 6). Two hypotheses may account for this missing link. Firstly, since normal deterioration of the sensory systems with age starts gradually, people may continuously habituate to their diminished perception and in this way not experience a noticeable decrease in food liking (Wysocki & Pelchat,

1993). Since pleasantness judgments are guided by previously acquired product concepts, it seems plausible that the elderly are able to compensate for sensory losses with the help of those mental images (Mojet et al., 2005). Support for this hypothesis can be found in recent cognitive neuroscience findings that challenge the traditional "brain-damage model of aging" (see review by Reuter-Lorenz & Lustig, 2005). In functional neuroimaging studies, elderly with no or only minimal losses in cognitive performance are reported to demonstrate age-related overactivation (i.e. greater brain activity) in other areas. This overactivation may reflect compensation and instead of characterizing aging as an inevitable process of brain damage and decline it should rather be characterized by functional reorganization - associated with gains and losses. So far, it has not been studied whether this change in neural activation pattern also occurs in sensory processing. Further neuroimaging research might throw more light on this issue.
An alternative hypothesis might be that the pathways of sensory and hedonic representations do not converge in the brain and are processed in different brain areas (De Araujo et al. 2003; Sewards, 2004). As a result, intensity perception may vary between the elderly and the young, while the hedonic aspects remain largely stable with increasing age. This alternative hypothesis may also explain why in the present thesis sensory acuity and preference for products with incorporated compensatory strategy were unrelated.

## *Sensory losses with age relate to food perception but not to food liking*

While sensory losses were observed on average for the elderly in the present studies, within the elderly groups one can find subjects with no or minimal sensory losses, when compared to the average of their younger counterparts. This finding clearly demonstrates the heterogeneous nature of sensory function in the elderly population.

### *Taste acuity*

On average, the young were better in supra-threshold identification of taste qualities than the elderly (chapter 6). This effect seems to be taste-specific since the young are better able than the elderly to identify salty and sour tastes, but no age difference is observed in the ability to identify sweet and bitter tastes. As mentioned in the introduction of this thesis, salty/sour tastes differ in their transduction mechanisms from sweet/bitter tastes. Interestingly, gustatory reaction time - defined as the interval between the onset of a taste stimulus and the beginning of the response- is reported to be significantly shorter for salty/sour tastes than for sweet/bitter tastes (Yamamoto & Kawamura, 1981). Thus, an explanation for this taste-specific age effect may be that the ionic mechanisms of taste transduction are more prone to age-related changes in functioning than the second-messenger mechanisms. This observation merits further research.

However, taste acuity of the elderly is neither related to food perception nor to food pleasantness (chapter 6), a finding that has been previously reported by Mojet et al. (2005). Thus, it seems unlikely that taste acuity might serve as an explanatory variable for differences in food perception and/or food liking with age.

*Olfactory acuity*

Olfactory acuity was measured with two different tests: the Dutch odour identification test (chapter 2 & 3) and the European test of olfactory capabilities (chapter 3, 4 & 6). Both tests measure orthonasal odour perception and they both enable classification of subjects according to their olfactory capabilities into normosmics, hyposmics and anosmics. On average, the young outperformed the elderly both in odour detection and odour identification in the present studies. One frequently mentioned hypothesis is that odour identification tasks are cognitively demanding and that age differences in these tests might partly be caused by differences in cognitive abilities and/or education level, due to recruitment of the young mainly from an university population, meanwhile the elderly are drawn from a more general population (Murphy, 1985; Cowart, 1989). But if this were true, one would expect the higher educated elderly to outperform the lower educated elderly, which is not the case (chapter 6). An alternative hypothesis would be that the elderly are generally more prone to postviral olfactory disorders i.e. olfactory dysfunction secondary to influenza, common colds and/or sinus infection. For example, age-related decline in the size of the olfactory epithelium are thought to make it more vulnerable to the consequences of these infections (Paik et al., 1992; Seiberling & Conley, 2004). Other elderly-specific causes for olfactory impairment may be found in systemic diseases (e.g. Hypertension, Diabetes Mellitus, Rheumatoid Arthritis), reduced oral health, chemotherapy/radiation, menopause, use of multiple medications, and/or neurodegenerative diseases.

Considerable doubts exist about the question whether or not retronasal flavour perception of the elderly can be predicted from olfactory sensitivity measured orthonasally (Duffy et al., 1999; Koskinen & Tuorila, 2004) and the results of the present studies are inconclusive on this point. On the one hand, elderly with low ETOC scores also perceived flavour intensities in foods as less intense (chapter 3). On the other hand, no difference in food flavour perception was observed between elderly with low, medium or high ETOC scores (chapter 6). Finally, olfactory sensitivity of the elderly is not, or only weakly related to food pleasantness (chapter 3, 4 & 6). Thus, it seems unlikely that it explains changes in food liking with increasing age.

### Somatosensory acuity

Different aspects of somatosensory acuity were measured. Firstly, the elderly appeared less efficient than the young in mastication (chapter 3 & 6). Secondly, the elderly had more difficulties than the young to correctly identify objects (letters) placed on the tongue (chapter 3). Thirdly, the elderly and the young did not differ in particle-size discrimination (chapter 3). Finally, the young were more sensitive to trigeminal stimulation by ammonia and menthol, but no age differences were observed for piperine and tannic acid (chapter 6).

Although some age effects of oral somatosensory acuity were observed with respect to food perception (chapter 6), no relationship with food pleasantness was observed. Thus, it seems unlikely that somatosensory acuity might account for changes in food liking with increasing age.

## Methodological considerations

### Test population

The young subjects participating in this study were mainly recruited from among the staff and students of the Wageningen University or the University of Utrecht, with the exception of the study presented in chapter 5 & 6. In the latter case, roughly half of the subjects were recruited from among the members of a sports club in Ede.

The elderly population studied in this thesis varied according to educational level and area of living. The elderly that participated in the studies presented in chapter 2 & 3 had a relative high level of education and they were all living in the urban area of Zeist, a suburban area near Utrecht. In contrast, roughly half of the elderly that took part in the study presented in chapter 4 lived in the rural area of Ede/Wageningen, whereas the other half lived in the urban area of Utrecht. The education level was not assessed in this study. In the studies presented in chapter 5 & 6, again roughly half of the elderly lived in the rural area of Doodewaard/ Herveld and the other half lived in the urban area of Zeist. The average education level was considerably lower for the rural than for the urban group of elderly. Elderly subjects living in rural areas are reported to eat "healthier" and to have a more positive attitude towards aging than elderly living in urban areas (Morgan et al., 2000; Paul et al., 2003). However, higher mental ability, which often goes along with higher education levels, is thought to lead to healthier lifestyles (Whalley et al., 2004). Furthermore, education is reported to protect cognitive performance in later life (Le Carret et al., 2003), to reduce the incidence of Alzheimer's disease (Karp et al., 2004) and to increase performance in psychophysical tests (Cowart, 1989).

Finally, the elderly population described in the present thesis belonged to the rather healthy and outgoing, the so-called "successfully" aged, group of elderly. Therefore, results obtained for this group of elderly subjects should not be generalized to other elderly populations such as nursing home residents.

### Cross-sectional versus longitudinal research

In sensory research on aging almost all studies - including the studies in the present thesis - are cross-sectional rather than longitudinal. Therefore, the results obtained are potentially vulnerable to a cohort effect, i.e. successive age cohorts may score differently at the same chronological age. The explanation of cohort differences may be found in nutritional, educational, environmental, medical, and/or experience differences between the cohorts. For example, food preferences of subjects, which are - at present - in their sixties have developed in wartime, a time of food shortage and only limited food choices. In contrast, subjects in their early twenties/thirties have never experienced food shortage and are used to choosing from a wide variety of foods.

### Variation within the group of elderly

Variation in many types of functioning is larger within a group of elderly subjects than within a group of young subjects. Nonetheless, the majority of studies in sensory research so far have concentrated on averaged tendencies between groups of young and elderly and neglected the substantial heterogeneity within the elderly group. The results of the present thesis clearly demonstrate that age itself is not a sufficient explanatory variable for food liking and that in future research further emphasis must be laid on the search for alternative explanations as well.

### Conjoint analysis

Traditional conjoint analysis, a classical market research tool, has proved to be of value as an additional statistical tool, providing extra information on individual subject responses (chapters 2-4, 6) and it might even aid in the segmentation of the elderly population for future research (Moskowitz & Silcher, 2005).

### Long term success of compensatory strategies

The majority of studies investigating compensation for sensory losses, including the present studies, were not designed to assess long-term success. Le Magnen (1956) studied odour-enrichment of food in rats. Notwithstanding the fact that the study was conducted with rats, its results may have some relevance for human eating behaviour. In his study, olfactory cues were found to play a role in regulating food intake. However, after an initial disturbance - either by introducing or by removing the odour-enrichment - the food intake system slowly recalibrated, resulting in no effects on the long term. In two studies, in which positive effects of compensation on food intake and nutritional status have been reported, the intervention periods studied were 3 weeks (Schiffman & Warwick, 1993) and 16 weeks (Mathey et al., 2001). However, these periods may not have been long enough to produce this recalibration effect in human eating behaviour. Thus, whether or not it is possible to increase food intake of the elderly on a long term with the help of compensatory product adjustments is subject for further research.

## Practical implications and future research directions

In health policies emphasis should be placed on strategies that enable the elderly to enjoy their food for as long as possible. For example, natural teeth should be maintained whenever possible since good oral health and natural teeth are not only important for food perception but might also help to minimize food avoidances among the elderly. Health policy-makers all over Europe currently underestimate the positive health/quality of life implications of the more costly maintenance of natural teeth. As a consequence, with short-term savings in mind, financial support for dental care is cut down to such an extent that elderly with low income can no longer afford best dental care.

Furthermore, it is time to re-consider the idea of compensating for sensory losses in foods for the elderly. The present thesis causes considerable doubt on whether compensation for sensory losses is needed to increase food liking of elderly people and on whether it can be practically achieved. In both sensory and brain research, there is growing evidence that sensory and hedonic aspects are independently processed in the brain. Although aging clearly takes a toll on perception, its influence on food liking seems rather limited. As a consequence, the possible role of sensory compensation strategies to increase food liking of the elderly has previously been overestimated. Further research is needed to establish additional strategies that may influence hedonic responses of the elderly and to compare these strategies - in their positive effect on hedonic responses - with sensory compensation strategies.

Even the healthy elderly population is highly heterogeneous and this will make compensation for sensory losses an almost impossible task in industrial product development. While some elderly will consider an applied compensatory strategy as a product improvement, others will consider it as an unnecessary and even unwelcome product change. In the present thesis, only subgroups within the elderly groups were observed that responded positively to the applied compensatory strategies. How to identify and define those subgroups, has to be investigated further if one wants to develop foods for the elderly with sensory compensation.

## Conclusions

Sensory acuity is decreased on average in the elderly. However, among the elderly one can find subjects with no or minimal sensory losses, when compared to the average of their younger counterparts. Thus, the elderly are highly heterogeneous in their sensory functioning.

Decreased sensory acuity, although causing changes in perception of some elderly, is obviously not causing a reduced food liking and thus cannot be the predominant reason for a diminished food intake. Non-sensory strategies taking other age-related factors into consideration - such as food wanting, loneliness, depression, reduced social interaction - may prove even more successful in increasing food intake and should be pursued in future research because an adequate dietary intake remains one of the keys to healthy ageing.

# Summary

# Chapter 1

The relative proportion of the elderly in the population is rapidly growing worldwide. According to current estimates, the proportion of people over 60 will almost double by 2050. Consequently there is a growing need to develop strategies, that enable the elderly to maintain their health and quality of life for as long as possible. Ensuring sufficient food intake plays an important role, since body weight tends to involuntarily decrease in elderly people. This weight loss in later life is associated with frailty and increased morbidity.

The prevalence of sensory impairment among the elderly is reported to be high and to increase with age. These age-associated losses in sensory function are believed to change food perception, to decrease food liking and eventually to modify food choice. Consequently, there is a growing need to understand more about age related changes both in food perception and food liking. What changes are seen in the later years of life and what are the implications of these changes?

Sensory systems perform a variety of common tasks such as vision, hearing touch, vibration, pain, taste and smell. Modulated by sensory systems, environmental stimuli are deconstructed at the peripheral level and then reconstructed in the brain to create perceptions.

Food perception does not usually depend on a single effect by one stimulus of one sensory modality. Instead, it is the result of simultaneous stimulation of at least three sensory systems: the gustatory (taste), the olfactory (smell) and the somatosensory system (touch, temperature, pain, body position). With increasing age perceptual and sensory functioning is thought to diminish, as sensory receptors age and neural efficiency drops. Interestingly, contradictory results are reported on whether or not food liking - presumably due to these age-related decreases in sensory function - changes with increasing age.

The aim of this thesis was to explore food perception and food liking with age. In particular, to examine differences in the perception of texture, flavour and/or irritant in foods between young subjects and elderly subjects and to investigate whether individual differences in food liking could be attributed to a diminished sensory acuity of elderly subjects.

# Chapter 2

The perception of texture, flavour and their interaction effects in white cream soups are studied in young subjects and elderly subjects. The elderly are found to be less sensitive to changes in the flavour profile of the soups than the young and their perception of creaminess is reduced. Solvent by flavour interaction effects are shown to be independent of age, whereas texture by flavour interaction effects are age specific. In addition to the intensities of the flavour and texture attributes, pleasantness is also assessed. No indication is found that the contribution of texture and flavour to food appreciation is different for the young and elderly. This study supports the assumption that age related differences in product perception exist.

## Chapter 3

Differences between two age groups in texture and flavour perception, in food appreciation and in texture and olfactory sensitivity are investigated. The elderly are found to differ from the young in their perception of both texture and flavour, but the observed texture flavour interaction effect is not different between the elderly and young. A decrease in the importance of flavour to food appreciation is observed for the elderly for the savoury but not for the sweet waffles. The young are more efficient in chewing and they are better in the oral letter recognition test. Among the elderly, olfactory sensitivity influences flavour intensity ratings, whereas poor texture sensitivity is not related to the perception of sensory attributes. It is concluded that the present study does not support the hypothesis that a different rate in the decline of the different sensory modalities with age will inevitably lead to a different integrated product concept.

## Chapter 4

Differences between elderly subjects and young subjects in their food liking and their olfactory sensitivity are investigated. Two food systems are used: custard desserts as a familiar food and tomato-spirulina health drinks as a novel food. Flavour enhancement/ enrichment, textural change, and/or irritant addition are incorporated as compensatory strategies into these foods. The food liking in the elderly is not generally increased by these compensatory strategies. Whatever compensatory strategy is chosen, subgroups are observed with an increase in product pleasantness. However, age-associated losses in olfactory acuity do not explain differences in food liking. It is concluded that the present study does not support the assumption that age-related impairment in olfactory sensitivity will inevitably lead to changes in food liking.

## Chapter 5

Just noticeable differences (JNDs) - the amount of change in physical stimuli necessary to produce a perceptible difference in sensation - are determined in custard desserts for both elderly and young subjects. The elderly require a larger stimulus increase in order to experience the same difference as the young. With respect to the experiment described in chapter 6 it is recommended to apply sufficiently large steps in cherry flavour and thickener concentration to ensure that not only the young but also the elderly perceive differences in the flavour and texture of the custards.

## Chapter 6

Differences between two age groups in sensory acuity, food perception and food liking are investigated. The young out performed the elderly in the sensory acuity tests. Several observed interaction effects are different between the elderly and the young. The majority of these differences manifest as flatter intensity slopes for the elderly. Subgroups of the elderly are observed in which applied compensatory strategies lead to an increase in food liking. However, these subgroups do not differ in their sensory acuity. The present study does not support the assumption that age-associated changes in perception - caused by a differential decline in sensory acuity - will affect the integrated product concepts of the elderly to an extent that will inevitably lead to changes in their food liking.

## Chapter 7

In this chapter it is concluded that the elderly perceive foods differently compared to the young. These age differences may originate from changes in the functioning of the sensory systems of the elderly at peripheral, central level or both. Possible changes at a peripheral level are anatomical changes in the olfactory system, reduced mastication due to dentures, decreases in total number of sensory receptor cells and/or a diminished saliva/mucus production. Various noise hypotheses may provide an explanation at a more central level. Decreases in neural signal intensity and/or increases in spontaneously firing neurons may lower the signal-to-noise ratio with age. Moreover, the signal-to-noise ratio may be decreased by increased stimulus persistence in the aged nervous system. In addition, it may become more difficult with increasing age to neglect irrelevant information, which would lead to an increase of noise at a psychological / perceptual level.

The second conclusion drawn in this chapter is that food liking is not reduced in the elderly, despite age-related changes in food perception due to diminished sensory acuity. Two hypotheses may account for this missing link. Firstly, since normal deterioration of the sensory systems with age starts gradually, people may continuously habituate to their diminished perception and do not experience a decrease in food liking.

Secondly, the pathways of sensory and hedonic representations do not converge in the brain and are processed by different areas in the brain. As a result intensity perception may vary between the elderly and the young, while the hedonic aspects remain largely stable with increasing age.
Furthermore, sensory losses (taste, olfaction, somatosensations) are observed on average for the elderly of the present studies. Within the elderly group one does find subjects with with minimal or no sensory losses, when compared to the average of their younger counterparts. Thus, the elderly are reported to be highly heterogeneous in their sensory functioning.
Finally it is concluded that decreased sensory acuity, although causing losses in perception of the elderly, is obviously not causing a reduced food liking and thus cannot be the predominant reason for a diminished food intake. Non-sensory strategies taking other age-related factors into consideration - such as food wanting, loneliness, depression, reduced social interaction - may prove to be even more successful in increasing food intake and should be pursued in future research because an adequate dietary intake remains one of the keys to healthy ageing.

# Samenvatting

## Hoofdstuk 1

Het aandeel van ouderen aan de wereldbevolking neemt in een hoog tempo toe. Recente berekeningen verwachten, dat het aantal van mensen ouder dan 60 jaar in 2050 bijna verdubbeld zal zijn. Het gevolg hiervan is een toenemende behoefte voor het ontwikkelen van strategien om de gezondheid en levenskwaliteit van ouderen in stand te houden. Een adequaat dieet speelt daarbij een belangrijke rol, omdat de eetlust van oudere mensen vaak ongewild afneemt. Dit leidt dan tot een gewichtsverlies die meestal gepaard gaat met zwakte en een afgenomen gezondheid. Een met de leeftijd toenemend verlies in sensorisch functioneren - zoals bijvoorbeeld ruiken en proeven - komt bij ouderen vaak voor. Aangenomen wordt dat zo'n verlies de voedselwaarneming verandert, vervolgens de appreciatie - in dit proefschrift gedefinieerd als het lekker vinden van het voedsel - verlaagt en daardoor uiteindelijk de voedselkeuze wijzigt. Derhalve is er een groeiende behoefte om meer van deze veranderingen te begrijpen, zowel van de waarneming als van de appreciatie van het voedsel. Welke veranderingen zijn er op latere leeftijd te zien en wat zijn de implicaties van deze veranderingen?

De sensorische systemen voeren een verscheidenheid van taken uit zoals zien, horen, voelen, proeven en ruiken. Deze sensorische systemen vormen stimuli uit de omgeving op perifeer niveau om en reconstueren deze in de hersenen om waarnemingen tot stand te brengen.

De waarneming hangt meestal niet af van één enkel effect door één sensorische modaliteit, maar is het resultaat van een gelijktijdige stimulatie van minstens drie sensorische systemen: smaak, geur en somatosensatorisch system (tastzien, temperatuur, de pijn, lichaamshouding). Verondersteld wordt dat het sensorisch functioneren af neemt wanneer men ouder wordt, omdat de sensorische receptoren verouderen en de neuronale efficiency daalt. Interessant is echter dat tegenstrijdige resultaten worden gemeld over wijzigingen in het wel of niet lekker vinden van voedsel die mogelijk het gevolg zijn van deze leeftijdsgerelateerde achteruitgang in het sensorisch functioneren.

Het doel van dit proefschrift is om de waarneming en de appreciatie van voedsel met het ouder worden te onderzoeken, met name om te zien of er verschillen in de waarneming van textuur, flavour (combinatie van geur en smaak) en/of irritant zijn tussen jongere en oudere proefpersonen en of individuele verschillen in appreciatie kunnen worden toegewezen aan een afgenomen sensorisch vermogen van ouderen.

## Hoofdstuk 2

De waarneming van textuur en flavour in een blanke gebonden soep wordt bestudeerd bij jonge en oudere proefpersonen. Ook hun mogelijke interactie effecten worden onderzocht. Er is sprake van sensorische interactie wanneer twee sensorische systemen elkaar wederzijds beïnvloeden. De ouderen blijken minder gevoelig voor veranderingen in het smaakprofiel van de soepen en zij vinden de romigheid wel minder sterk. De soepbasis-smaak interactie effecten bleken onafhankelijk van de leeftijd te zijn, terwijl de textuur-smaak interactie effecten leeftijd-specifiek bleken. Naast de intensiteit van de smaak-en textuurattributen, is ook de aangenaamheid gemeten. Er wordt geen aanwijzing gevonden dat de bijdrage van textuur en aroma aan appreciatie verschillend is voor de jongeren en de ouderen. Dit experiment verleent dus steun aan de veronderstelling dat er leeftijdsgerelateerde verschillen in productwaarneming bestaan.

## Hoofdstuk 3

De textuur- en flavourwaarneming, de voedselappreciatie alsmede de textuur- en reukgevoeligheid worden onderzocht voor de twee leeftijdsgroepen. De ouderen nemen zowel textuur als smaak op zich anders waar dan de jongeren, maar het gevonden interactie-effect tussen textuur en smaak blijkt niet verschillend.. Het relatieve belang van het flavour voor de appreciatie is afgenomen bij de ouderen voor de hartige maar niet voor de zoete wafels. De jongeren kauwen efficiënter en zij zijn beter in het herkennen van letterfiguren op de tong. De geurgevoeligheid beïnvloedt de flavourintensiteit bij de ouderen, terwijl de geringere textuurgevoeligheid geen verband laat zien met de waarneming van de sensorische attributen. De huidige studie verleent dus geen steun aan de hypothese dat een verschil in afnamesnelheid van de diverse sensorische modaliteiten onvermijdelijk tot een veranderd geïntegreerd productconcept zal leiden.

## Hoofdstuk 4

In dit hoofdstuk wordt de mogelijke relatie tussen voedselappreciatie en geurgevoeligheid van ouderen en jongeren onderzocht. Twee soorten voedingsmiddelen worden gebruikt: een vla dessert als een bekend voedingsmiddel en een tomaat-spirulina gezondheidsdrank als een nieuw te introduceren voedingsmiddel. Een versterking/verrijking van het flavour, een verandering in de textuur, en/of een toevoeging van een prikkeling worden gebruikt als compensatie strategieën in deze voedingsmiddelen. De appreciatie door de ouderen wordt over het algemeen niet verhoogd met deze compensatie-strategieën. Er worden subgroepen met een verhoogde productwaardering gevonden onafhankelijk van de gekozen strategie. Het leeftijd-gerelateerde verlies in geurgevoeligheid verklaart niet de verschillen in appreciatie. De huidige studie verleent dus geen steun aan de veronderstelling dat een leeftijdsafhankelijke achteruitgang in geurgevoeligheid onvermijdelijk zal leiden tot een verandering in de voedselappreciatie.

## Hoofdstuk 5

Just noticeable differences (net waarneembare verschillen in concentratie) - worden bepaald in vladesserts voor zowel oudere als jongere proefpersonen. Er is een grotere toename in concentratie nodig voor de ouderen om een zelfde verschil waar te kunnen nemen als de jongeren. Met betrekking tot het experiment dat in hoofdstuk zes wordt beschreven verdient het aanbeveling om voldoende grote stappen in de toename van de concentratie van kersenaroma en van de verdikker toe te passen om ervoor te zorgen dat niet alleen jongeren maar ook de ouderen verschillen in smaak en textuur van de vla waarnemen.

## Hoofdstuk 6

Vervolgens wordt onderzocht of er tussen de twee leeftijdsgroepen verschillen zijn in sensorische gevoeligheid en in waarneming en appreciatie van voedsel. De jongeren presteren beter dan de ouderen in de sensorische gevoeligheidstests. Verscheidene waargenomen interactie-effecten zijn verschillend voor de ouderen en de jongeren. De meerderheid van deze verschillen tonen voor de ouderen een vlakkere intensiteitshelling met toegenomen concentratie. Er worden subgroepen van ouderen waargenomen voor wie de toegepaste compensatiestrategieën een verhoogde appreciatie laten zien. Deze subgroepen verschillen echter niet in sensorische gevoeligheid. De huidige studie verleent geen steunt aan de veronderstelling dat de leeftijdgerelateerde veranderingen in waarneming - veroorzaak door een differentiële afname van gevoeligheid in de verschillende sensorische modaliteiten - de geïntegreerde productconcepten van ouderen zodanig zullen beïnvloeden, dat dit onvermijdelijk tot veranderingen in hun appreciatie zal leiden.

## Hoofdstuk 7

In dit hoofdstuk wordt geconcludeerd dat ouderen voedsel anders waarnemen dan jongeren, meestal als minder sterk.. Deze leeftijdsverschillen kunnen ontstaan door veroudering in het functioneren van de sensorische systemen op perifeer of centraal niveau of beide. Anatomische veranderingen in de reuk, een verslechterd kauwgedrag veroorzaakt door het dragen van een kunstgebit, een afname in het aantal receptorcellen en/of een afgenomen speeksel/ mucusproductie zijn mogelijke veranderingen op perifeer niveau. Verscheidene ruishypothesen kunnen een verklaring op centraal niveau verstrekken. Afgenomene neuronale signaalintensiteit en/of een toename in spontaan vurende neuronen kunnen de signal-ruis ratio met het ouder worden doen afnemen. De signal-ruis ratio kan bovendien zijn verlaagd in het verouderde zenuwstelsel door het aanhouden van de stimulus. Daarnaast kan het moeilijker worden om irrelevante informatie, leidend tot een toegenomen ruis op psychologisch/waarnemings niveau, te negeren.

De tweede conclusie die in dit hoofdstuk wordt getrokken is dat de voedselappreciatie niet afgenomen is bij de ouderen, ondanks de leeftijdsgerelateerde veranderingen in waarneming veroorzaakt door een verminderde sensorische gevoeligheid. Ter verklaring van deze veronderstelde missing link kunnen twee hypotheses geformuleerd worden. Ten eerste kan de ouder wordende mens voortdurend habitueren aan zijn verminderde waarneming en geen daling in appreciatie opmerken, aangezien de normale achteruitgang van het sensorische systeem met leeftijd geleidelijk aan begint. Ten tweede, convergeren de banen van de sensorische en de hedonische representaties niet in de hersenen maar worden in verschillende gebieden van de hersenen verwerkt. Dientengevolge is het mogelijk dat de intensiteitswaarneming varieert tussen de ouderen en de jongeren, terwijl de hedonische aspecten grotendeels stabiel blijven met het ouder worden.

Hoewel over het algemeen sensorische verliezen (smaak, reuk, tastzin) waargenomen worden voor de ouderen in de huidige studies worden er binnen deze groep ook ouderen gevonden zonder of met minimale sensorische verliezen vergeleken met het gemiddelde van de jongeren. De ouderen zijn dus hoogst heterogeen in hun sensorische functioneren.

Ten slotte wordt geconcludeerd dat een afgenomen sensorische gevoeligheid, hoewel leidend to veranderingen in de waarneming van ouderen, duidelijk niet de overheersende reden is voor een afgenomen eetlust. In plaats daarvan kunnen wellicht niet-sensorisch strategieën die andere leeftijdsgerelateerde factoren in overweging nemen - zoals eenzaamheid, depressie, verminderde sociale interactie - meer succesvol blijken en in de toekomst onderzocht worden omdat een adequaat dieet voor ouderen één van de voornaamste factoren blijft voor een gezond ouder worden.

# Zusammenfassung

# Kapitel 1

Der Anteil der älteren Menschen an der Weltbevölkerung nimmt ständig zu. Aktuelle Prognosen gehen davon aus, dass sich die Anzahl der über 60 Jährigen bis 2050 verdoppeln wird. Auf Grund der damit steigenden gesellschaftlichen Bedeutung dieser Bevölkerungsgruppe gilt es, Strategien zur Aufrechterhaltung sowohl der Gesundheit als auch der Lebensqualität von älteren Menschen zu entwickeln. Eine adäquate Nahrungsaufnahme spielt dabei eine wichtige Rolle, da sich mit zunehmendem Alter häufig die Nahrungszufuhr unbewußt vermindert. Dies führt zu einer ungewollten Gewichtsabnahme, welche mit einem gesteigerten Krankheitsrisiko und einer erhöhten Sterberate einher geht.

Studien zufolge treten mit steigendem Alter verstärkt funktionelle Beeinträchtigungen der Sinnesorgane auf. Diese gelten als mögliche Ursache für eine veränderte Wahrnehmung von Lebensmitteln, woraus möglicherweise ein Appetitverlust und eine veränderte, eingeschränktere Nahrungsmittelauswahl resultiert. Deshalb ist es wichtig, altersbedingte Veränderungen in der Wahrnehmung und Beliebtheit von Lebensmitteln zu erforschen. Welche Veränderungen können bei älteren Menschen beobachtet werden und was sind die Folgen dieser Veränderungen?

Die sensorischen Systeme des Menschen sind verantwortlich für die Aufnahme und Verarbeitung von Reizen aus der Umwelt, so z.B. beim Sehen, Hören, Fühlen, Schmecken und Riechen. Mit Hilfe der sensorischen Systeme werden Reize aus der Umgebung über die Sinnesorgane aufgenommen, als Impulse an das Zentrale Nervensystem weitergeleitet und dort zu Wahrnehmungen verarbeitet.

Die Wahrnehmung von Lebensmitteln ist in der Regel nicht nur von einer Sinnesmodalität abhängig, sondern ist das Ergebnis der gleichzeitigen Stimulation und Integration mindestens dreier senorischer Systeme: des gustatorischen (Geschmack), des olfaktorischen (Geruch) und des taktilen/somatosensorischen Systems (Fühlen, Temperatur, Schmerz, Körperlokalisation). Als Ursache für eine allgemeine Funktionsabnahme in den sensorischen Systemen bei älteren Menschen werden zum einen das Altern der Rezeptoren selbst und zum anderen eine Verlangsamung der Impulseffizienz angesehen. Es gibt jedoch widersprüchliche Ergebnisse darüber, ob diese altersbedingten Funktionsverluste zu veränderten Geschmacksvorlieben führen oder nicht.

Ziel dieser Doktorarbeit ist es, neue Erkenntnisse sowohl über die Wahrnehmung als auch über Geschmacksvorlieben im Alter zu erhalten. Besondere Aufmerksamkeit wird der sensorischen Integration in der Wahrnehmung von Textur, Flavour (Geruch und Geschmack) und/oder Irritation von jungen und älteren Probanden bei Lebensmitteln gewidmet. Ein weiterer Schwerpunkt liegt in der Erforschung potenzieller Unterschiede in der Beliebtheit von Lebensmitteln bei älteren Probanden auf Grund unterschiedlicher sensorischer Fähigkeiten.

## Kapitel 2

Mit Hilfe einer Cremesuppe wird die Textur- und Flavourwahrnehmung sowie deren Interaktionen bei jungen und älteren Probanden untersucht. Von sensorischen Interaktionen spricht man, wenn sich zwei sensorische Systeme gegenseitig beeinflussen. Die älteren Probanden sind gegenüber Veränderungen im Flavourprofil der Suppen weniger empfindsam als die jungen Probanden. Die älteren Probanden nehmen die Produkte außerdem insgesamt als weniger cremig wahr. Es stellt sich heraus, dass die Wahrnehmung der Interaktion zwischen Textur und Flavour altersabhängig ist. Neben der Intensität von Textur- und Flavourattributen wird auch die Beliebtheit der Produkte gemessen. In Bezug auf die Bedeutung von Textur und Flavour für die Produktbeliebtheit werden jedoch keine Hinweise auf Unterschiede zwischen den jungen und den älteren Probanden gefunden. Diese Studie unterstützt die Annahme, dass altersbedingte Unterschiede in der Produktwahrnehmung existieren.

## Kapitel 3

Die Textur- und Flavourwahrnehmung, sowie die Produktpräferenz und die taktile und olfaktorische Sensitivität wird in zwei Altersgruppen untersucht.

Dabei zeigen die älteren Probanden im Vergleich zu den jüngeren Probanden eine unterschiedliche Wahrnehmung von Textur und Flavour von Waffeln. Kein Altersunterschied wird jedoch in der Interaktion zwischen Textur und Flavour gefunden. Bei den älteren Probanden kann ein Rückgang der Bedeutung des Flavours für die Beurteilung der herzhaften Waffeln beobachtet werden. Dies kann jedoch für die süßen Waffeln nicht bestätigt werden. Die jungen Probanden verfügen über ein besseres Kauvermögen und schneiden beim oralen Erkennen von Buchstaben besser ab. Die olfaktorische Sensitivität von älteren Menschen beeinflusst deren Flavourintensitätsbewertungen, wohingegen die taktile Sensitivität keinerlei Einfluss auf die Wahrnehmung sensorischer Eigenschaften hat. Daher wird die Hypothese nicht bestätigt, dass der unterschiedlich schnelle Funktionsverlust der verschiedenen Sinnesorgane unweigerlich zu neuen, integrierten Produktkonzepten für ältere Menschen führt.

## Kapitel 4

Ein möglicher Zusammenhang zwischen der Lebensmittelpräferenz und der olfaktorischen Sensitivität von älteren und jungen Probanden wird untersucht.
Dazu werden zwei Lebensmitteltypen verwendet: am Markt etablierte Cremedesserts und neuartige Tomaten-Spirulina Gesundheitsgetränke. Flavourverstärkung/-anreicherung, Texturveränderungen und/oder Hinzufügen von trigeminaler Irritation zu diesen Lebensmitteln werden hierbei angewendet, um potenzielle Sinnesverluste zu kompensieren. Trotz der angewendeten Kompensationsstragien steigen die Produkte bei den älteren Probanden nicht generell in der Beliebtheit. Andererseits können für jede Strategie Untergruppen gefunden werden, bei denen die Beliebtheit der Produkte ansteigen. Jedoch können diese Unterschiede nicht durch altersbedingte Verluste in olfaktorischer Sensitivität erklärt werden.
Somit bestätigt diese Studie nicht die Annahme, dass eine altersbedingte Beeinträchtigung der olfaktorischen Sensitivität unvermeidlich zu Veränderungen bezüglich der Beliebtheit von Lebensmitteln führt.

## Kapitel 5

Eben merkliche Unterschiede (engl. just noticeable differences) - kleinste Reizunterschiede, die man gerade noch feststellen kann - werden zwischen jungen und älteren Probanden mit Hilfe eines Cremedesserts bestimmt. Die älteren Probanden benötigen eine größere Reizerhöhung, um denselben Unterschied wahrzunehmen als junge Probanden. Hinsichtlich des in Kapitel 6 beschriebenen Experiments wird empfohlen, größere Konzentrationsunterschiede bei Flavour und Verdicker zu verwenden, um sicherzustellen, dass Flavour- und Texturunterschiede in den Cremedesserts nicht nur für die jüngeren sondern auch für die älteren Probanden wahrnehmbar sind.

## Kapitel 6

Sowohl die Lebensmittelwahrnehmung und -präferenz als auch die sensorischen Fähigkeiten werden in älteren und jungen Probanden untersucht. Die jungen Probanden verfügen im Allgemeinen über bessere sensorische Fähigkeiten. Mehrere der gefundenen Interaktionen in der Wahrnehmung sind unterschiedlich bei älteren und jungen Probanden. Die Mehrheit dieser Unterschiede manifestieren sich als flachere Intensitätskurven bei den älteren Probanden. Außerdem können bei den älteren Probanden Untergruppen ermittelt werden, für die mit Hilfe einer Kompensationsstrategie die Lebensmittelbeliebtheit ansteigt. Nichtsdestotrotz unterscheiden sich diese Untergruppen nicht in ihren sensorischen Fähigkeiten. Somit bestätigt diese Studie nicht die Annahme, dass altersbedingte Funktionsbeeinträchtigungen der Sinnesorgane die Wahrnehmung von Lebensmitteln soweit verändern, dass deren Beliebtheit bei älteren Menschen absinkt.

## Kapitel 7

In diesem Kapitel wird die Schlussfolgerung gezogen, dass ältere Menschen Lebensmittel anders wahrnehmen als junge Menschen, meistens als weniger intensiv. Diese Unterschiede in der Wahrnehmung können ihre Ursache in einer sowohl auf peripherem als auch zentralem Niveau veränderten Funktion der sensorischen Systeme im Alter haben.

Mögliche Veränderungen auf dem zentralen Niveau sind anatomische Veränderungen des olfaktorischen Systems, durch künstliche Gebisse verursachtes verschlechtertes Kauen und eine verringerte Anzahl sensorischer Rezeptoren und/oder eine reduzierte Speichel-/Schleimproduktion.

Verschiedene Signal-zu-Rausch-Hypothesen können eine Erklärung auf zentralem Niveau liefern. Ein Rückgang der Signalsintensität und/oder eine Zunahme spontaner neuronaler Aktivität könnten mit zunehmendem Alter das Signal-zu-Rausch-Verhältnis verringern. Außerdem könnte das Signal-zu-Rausch-Verhältnis durch eine erhöhte Reizausdauer im gealterten Nervensystem verringert werden. Des Weiteren könnte es mit erhöhtem Alter schwieriger werden, irrelevante Informationen nicht zu beachten und folglich würde mehr "psychologischer Rausch" entstehen.

Als zweites wird in diesem Kapitel gefolgert, dass die Beliebtheit von Lebensmitteln bei älteren Menschen nicht abnimmt, obwohl sich deren Wahrnehmung durch altersbedingte Funktionsbeeinträchtigungen der Sinnesorgane verändert. Für diese fehlende Verbindung gibt es zwei mögliche Hypothesen. Erstens: Die normale, altersbedingte Beeinträchtigung der Funktion der Sinnesorgane beginnt langsam. Dadurch gewöhnen sich die Menschen an die geringere Reizwahrnehmung und erfahren somit keinen Rückgang in der Lebensmittelbeliebtheit. Zweitens: Die sensorischen und hedonischen Signalwege konvergieren nicht im Gehirn, sondern werden von unterschiedlichen Gehirnbereichen verarbeitet. Darausfolgend ist es möglich, dass die Intensitiätswahrnehmungen zwischen älteren und jungen Menschen variieren, aber zur gleichen Zeit die hedonischen Aspekte mit zunehmendem Alter stabil bleiben.

Des Weiteren werden bei den älteren Probanden im Durchschnitt sensorische Funktionsverluste (Geschmack, Geruch, Taktil) beobachtet. Innerhalb der älteren Gruppe werden Probanden gefunden, die im Vergleich zum Durchschnitt der jungen Probanden keine oder nur minimale Verluste in ihrer sensorischen Funktion aufweisen. Dies verdeutlicht die starke Heterogenität von älteren Menschen in ihrer sensorischen Funktionsfähigkeit.

Letztendlich wird die Schlussfolgerung gezogen, dass ein altersbedingter Funktionsverlust in den sensorische Systemen bei älteren Menschen zwar zu einer Veränderung der Lebensmittelwahrnehmung führt, dies aber nicht zu einem Rückgang in der Lebensmittelbeliebtheit führt und somit nicht hauptverantwortlich dafür sein kann, dass ältere Menschen weniger essen. Stattdessen wird es für möglich gehalten, dass Strategien erfolgsversprechender sein könnten, die andere altersrelevante Faktoren, wie zum Beispiel Einsamkeit, Depression und weniger soziale Kontakte, mit einbeziehen. Da eine ausreichende Nährstoffzufuhr weiterhin von großer Bedeutung für ein gesundes Altern ist, könnte dies ein Ansatzpunkt für weitere Forschungen sein.

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# Acknowledgements

Five amazing years have passed and there are many people to thank for their support and encouragement, without whom this thesis would not have been possible.

Allereerst wil ik mijn promotoren Jan Kroeze en Kees de Graaf bedanken voor hun begeleiding, wetenschappelijke discussies en constructieve kritiek. Bedankt voor het vertrouwen dat jullie altijd in mij hebben getoond. Mijn zeker zo grote dank gaat uit naar mijn co-promoter Jos Mojet. Gedurende deze vijf jaar ben jij mijn dagelijkse begleidster geweest en heb ik veel van jou geleerd - zo wel op het wetenschappelijke als op het menselijk vlak. Tijdens onze besprekingen wist je mij altijd wetenschappelijk uit te dagen en weer een voor mij nieuwe draai aan de discussie te geven. Verder heb jij mij met veel geduld het schrijven van publicaties geleerd. Ook wil ik je bedanken voor alle steun bij het combineren van moederschap en wetenschappelijk onderzoek. Nancy Holthuysen, Mariska Nijenhuis, Rudi van Doorn, Ilse Polet en Monique Theunis wil ik bedanken voor hun tomeloze inzet tijdens mijn experimenten. Nancy en Mariska, jullie heben mij ook tijdens het schrijven enorm gesteund, samen met jullie heb ik altijd plezier gehad en ik ben blij dat jullie mijn paranimfen willen zijn. Verder wil ik Harold Bult bedanken omdat hij - als vervanger tijdens mijn zwangerschap - de uitvoering van een aantal experimenten van mij heeft overgenomen toen ik bij Arne met de laatste loodjes liep. Bedankt voor jouw enthousiaste inzet, wetenschappelijke discussies, statistische steun en de vele leuke gesprekken over onze kinderen. Ik heb onze samenwerking altijd als erg prettig ervaren. Ook bedank ik Marjan Beetstra, die in het kader van haar afstudeervak een grote bijdrage geleverd heeft aan het werk dat in hoofdstuk 6 beschreven staat.

Natuurlijk wil ik ook alle oudere en jongere proefpersonen bedanken. Zonder jullie medewerking was dit onderzoek niet mogelijk geweest! I would also like to thank all members of the HealthSense project for doing exciting research in a multi-national setting. Special thanks goes to my “partners in crime” within the workpackage 5, the Irish PhD student Ciaran Forde and the Finnish PhD student Sari Koskinen. Als “gast” heb ik mij altijd zeer welkom gevoeld op het ATO/A&F/AFSG. Alle collega's van de afdeling Consumer & Market Insight hebben mij een fijne tijd bezorgd, waarvoor ik hen hartelijk dank. Vooral René Koster wil ik bedanken voor de vanzelfsprekendheid waarmee hij mij heeft opgenomen in de groep. Thanks to WCFS for giving me the opportunity to do this PhD research. Hugo Weenen, René de Wijk and Eric Dransfield are especially acknowledged for undertaking the tideous task of linking my “sattelite” project B-700 to the B-008/B-013 research activities.

Mijn kamergenoten Jacques, Marjolein, Eva, Neleke, Wim, Jendo en Teresa wil ik in het bijzonder bedanken voor de gezelligheid. Mede dankzij jullie heb ik met veel plezier in Wageningen gewerkt. Friends will be friends! Thanks Cordula & Michael, Sandra & Leen, Nicole & Family, Bina & Fritz, Matthias, Jodie, Markus & Sylvie, Eric for all your visits, phone calls and emails to us. And please know that you are always welcome!
Mark Hampson is acknowledged for his valuable corrections of the English in this thesis. Jos Mojet, Jan de Valk (Nederlands) and Sabine Jörg (Deutsch) are acknowledged for their help with the translation of the summary.
Als werkende moeder ben ik niet alleen gezegend met Joke als beste gastmoeder maar ook met de De Valks als het beste gastgezin van heel Nederland. Beste Joke, niet alleen Arne is blij dat jij altijd vrij bent als ik werken moet - ik ook! Bedankt voor jouw uitstekende zorg voor Arne & Jasper, maar ook voor alle andere hulp; het laten meebeleven van Nederlandse gewoontes en niet in de minste plaats voor de lekkere koffie 's-ochtends! Jan (groot), Loes en Jan (klein), bedankt dat Arne & Jasper niet alleen mogen genieten van een gastmoeder maar ook van een gastvader, gastzus and gastbroer. Bedankt ook voor een aantal keren spoedopvang ;-)
Diese Doktorarbeit ist meinem geliebten Omchen Helene Goller gewidment als Dank für ihre Liebe, ihre Geduld, die vielen Hörnchen und die wunderbaren Geschichten von Früher. Mama und Papa, bei euch möchte ich mich für ein liebevolles Zuhause bedanken und dafür, dass ihr mich in allem, was ich mir auch in den Kopf gesetzt hatte, unterstützt habt. Darüberhinaus möchte ich mich aber auch noch für die vielen Male bedanken, die ihr uns in 's-Hertogenbosch besucht habt und dabei oftmals die Kinderbetreuung übernommen habt. Klaus, Christiane & Maike und Sabine, Michael, Nina & Niklas, auch wenn wir uns nicht häufig sehen, so ist es doch jedesmal sehr schön. Danke für eure Besuche und eure Unterstüzung aus "der Ferne". Klaus und Sabine, ich finde es besonders schön, dass wir als Geschwister nun alle zur gleichen Zeit Kinder haben.
Zu guter Letzt möchte ich mich bei meinen drei Göhlmännern zu Hause bedanken! Hinrich, danke für deine Liebe, für dein unerschütterliches Vertrauen in mich und für die vielen spannenden, und manchmal auch ein wenig kontroversen, Disskusionen mit dir. Desweiteren möchte ich aber auch deine praktische Hilfe nicht unerwähnt lassen, insbesondere stundenlanges Pudding mixen, Kinder hüten und deine Engelsgeduld beim Layout. Thanks for loving me just as I am! Arne und Jasper, meine zwei Lümmel! Wisst ihr eigentlich, wie lieb ich euch habe? "Bis zum Mond und wieder zurück habe ich euch lieb". Endlich, Mamas Buch ist fertig!

# Curriculum vitae

Stefanie Kremer was born on June 15th, 1975 in Marburg/Lahn, Germany. She graduated from the Alfred-Wegener-Gymnasium in Kirchhain in 1994 and spent a GAP-year working as Junior Housemistress at the Rye St. Antony girls boarding school in Oxford, Great Britain. After studying for one year to become a teacher at the Pädagogische Hochschule Heidelberg, she switched courses and went on to study Ökotrophologie (Food Science and Nutrition) at the University for Applied Sciences in Fulda, specialising in sensory science. During her studies she received a scholarship, awarded by the Carl Duisberg Gesellschaft e.V., Köln, to spent 6 months as an international student at the University of Melbourne, Australia. In 2000 she finalised her diploma degree with a sensory consumer study that was conducted in the R&D department of Imperial Meat Products (SaraLee) in Lovendegem, Belgium. From January 2001 to January 2006, she was employed as a PhD-fellow at the University of Wageningen, Department of Social Sciences, where she was seconded to the Wageningen Centre for Food Sciences. Stefanie is married to Hinrich and is the mother of Arne and Jasper.

Cover: Stefanie Kremer & Hinrich Göhlmann
Design: Hinrich Göhlmann
Printing: Ponsen & Looijen bv. Wageningen, The Netherlands