

Flavor enhancement of food as a stimulant for food intake in elderly people

Natasja H Essed

THESIS COMMITTEE

Thesis supervisors

Prof dr ir C de Graaf

Professor of Sensory Research and Eating Behavior, division of Human Nutrition,
Wageningen University

Prof dr WA van Staveren

Emeritus Professor of Nutrition and Elderly, division of Human Nutrition,
Wageningen University

Other members

Prof dr ir MAJS van Boekel, Wageningen University

Dr J Mojet, Wageningen University and Research centre

Prof dr JJ van Binsbergen, UMC St Radboud Nijmegen

Prof H Tuorila, University of Helsinki, Finland

This research was conducted under the auspices of the Graduate School VLAG.

Flavor enhancement of food as a stimulant for food intake in elderly people

Natasja H Essed

THESIS

submitted in partial fulfillment of the requirements for the degree of doctor
at Wageningen University
by the authority of the Rector Magnificus
Prof Dr MJ Kropff,
in the presence of the
Thesis Committee appointed by the Doctorate Board
to be defended in public
on Monday 14 December 2009
at 1.30 PM in the Aula

Natasja H Essed

Flavor enhancement of food as a stimulant for food intake in elderly people,
160 pages

Thesis Wageningen University, Wageningen, NL (2009)

With references, with summaries in Dutch and English

ISBN 978-90-8585-491-3

*"I have this theory that dark chocolate slows down the aging process . . .
It may not be true, but do I dare take the chance?" – Anonymous*

ABSTRACT

It is often speculated that the age related decline in taste and smell performance can add to the decreased food intake among elderly by causing a change in liking of food. Flavor enhancement (by adding a taste and/or an odor to enhance or intensify the flavor of the food) has been suggested to counteract for the diminished taste and smell performance in order to increase liking and subsequently intake among elderly people. However, there is no clear relationship between an impaired taste and smell functioning and flavor enhancement. In addition, the results of studies on the effect of flavor enhancement on intake are inconsistent. In this thesis we investigated the effect of flavor enhancement on liking and/or food intake in elderly people and the relationship between an altered taste and/or smell performance and liking of flavor-enhanced foods.

When flavor enhancement is used as an approach to stimulate intake, it is important to know how elderly respond to a daily repeated exposure of a food. We first examined the effect of repeated exposure to fruit drinks with different sweet intensities on intake, pleasantness and boredom in young and non-institutionalized elderly adults. Second, the relationship between an impaired taste and smell performance and the liking and intake of tomato soup enhanced with MSG (0.12%) and celery powder (3 g) was studied. Third, the effect of flavor enhancement on liking and intake has been examined in nursing home elderly people that received MSG (0.3%) and/or flavors (700 mg) sprinkled over the protein component of their hot meal during 16 weeks. As last, to study the effect of a determined optimal preferred amount of MSG on food intake, we added 0.5% MSG (optimal amount) to mashed potatoes and 2% MSG to spinach and ground beef and measured the intake of these foods among institutionalized elderly.

The results showed that the elderly experienced no increase in boredom and pleasantness after daily repeated exposure to fruit juices. Elderly with an impaired taste and/or smell functioning did not show an increase in liking and intake of the flavor-enhanced soup. Thus, no relationship was established between an impaired chemosensory performance and flavor enhancement. Flavor enhancement also did not increase liking and energy intake of the hot meal after 16 weeks nor did an optimal preferred amount of MSG increase intake of mashed potatoes, spinach and ground beef.

A standardized flavor enhancement of foods did not prove an effective approach to increase food intake in frail elderly people. Therefore we reviewed the literature to obtain a recent picture on the causes of taste and smell loss in the elderly and to examine if the available methods to measure these losses are adequate. Results of the review showed that elderly are a heterogeneous group with various degrees of taste and smell loss and that the applied methods can distinguish the variations. This result implies a more individual, tailored taste and/or flavor enhancement of foods when it is part of a treatment or used in the prevention of undernutrition. We proposed a future strategy for flavor enhancement of foods in which we embedded the results of this review.

CONTENTS

Chapter 1	General introduction	8
Chapter 2	The effect of repeated exposure to fruit drinks on intake, pleasantness and boredom in young and elderly adults	27
Chapter 3	No effect on intake and liking of soup enhanced with MSG and celery powder among elderly people with olfactory and/or gustatory loss	43
Chapter 4	No effect of 16 weeks flavor enhancement on dietary intake and nutritional status of nursing home elderly	59
Chapter 5	Optimal preferred MSG concentration in potatoes, spinach and beef and their effect on intake in institutionalized elderly people	77
Chapter 6	General discussion	95
	Summary	146
	Samenvatting	150
	Dankwoord / Acknowledgements	155
	About the author	158

1

General introduction

It is speculated that the age related decline in taste and in particular smell sensitivity (Stevens et al 1984, Murphy 1993, Murphy et al 2002, Schiffman 1993) can add to the decreased food intake in the elderly population (Rolls 1999). In older people with a smell loss duration of < 3 yrs, an impaired olfaction may alter the enjoyment of food (Ferris and Duffy 1989). Since palatability is an essential factor to promote food intake (De Castro 2002) it is assumed that a change in liking (preference) may further reduce intake in the elderly (Figure 1). So far there is little evidence to support these associations (Mattes 2002).

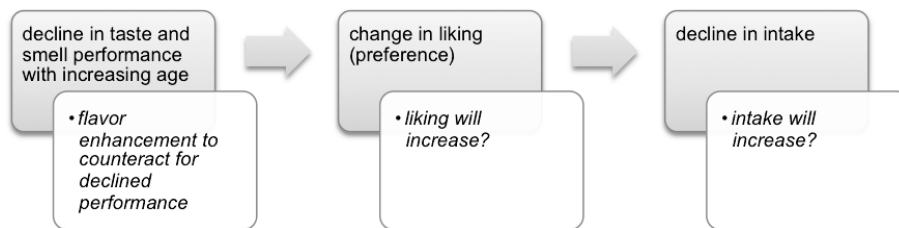


Figure 1. Hypothesized model of how a decline in taste and smell performance may influence food intake in elderly people (grey boxes) and the hypothesized solution (italic) to increase liking and/or intake with flavor enhancement of food.

Aging is also accompanied by a reduced dietary variety, which could add to dietary inadequacies. The reduced variety may be partly explained by a decreased sensitivity for boredom after repeated monotonous exposure to foods. However, whether the lower sensitivity occurs with all food products under all circumstances is not clear.

This thesis focuses on the effect of flavor enhancement of food as part of the treatment and prevention of undernutrition in elderly people. At present, it is unclear whether or not a higher taste and/or odor concentration in food actually increases liking and/or intake.

On the one hand, there are studies showing that on average elderly people prefer higher taste and/or odor concentrations in certain solutions and food products compared to younger people (de Graaf et al 1994, Griep et al 1997, Murphy & Withee 1986, Kozłowska et al 2003, De Jong et al 1996). However, they failed in their attempt to relate the preference for a higher level of flavor to a higher consumption (Griep et al 1997, De Jong et al 1996). On the other hand, several other studies

suggest that increasing the pleasantness with aromas and/or monosodium glutamate (MSG) as a way to compensate for the smell and taste losses increases food intake (Bellisle et al 1991, Bellisle et al 1996, Schiffman & Warwick 1993, Schiffman 1998, Mathey et al 2001). Because of this contradiction, there is insufficient evidence to label and implement flavor enhancement as a functional tool to increase food intake in the elderly. Furthermore, the relationship between an impaired taste and smell functioning and liking of flavor-enhanced foods has not been established (Koskinen et al 2003b). Thus at present, is not certain if flavor enhancement compensates for the decline in taste and smell performance. Therefore, additional research is needed to verify the effect of flavor enhancement/higher stimuli concentration on intake and its assumed compensatory action. Furthermore, when flavor enhancement of foods is used as an instrument to stimulate food and nutrient intake, it is important to know how elderly will respond to a daily repeated exposure to particular foods.

In this thesis we examined:

- the effect of repeated exposure to several sweetness levels in fruit juices on intake, pleasantness and boredom
- the relationship between an altered taste and smell performance and liking of flavor-enhanced foods
- the effect of a long-term treatment of flavor enhancement with MSG and/or flavors (mixtures of odorous molecules) on intake
- the optimal preferred concentration of MSG in foods and its effect on intake.

In this chapter we first describe the knowledge at the start of the research for this thesis (by about 2003) on 1) a lower dietary intake, 2) a decline in taste and smell performance, and 3) a decreased sensitivity to a repeated monotonous exposure treatment in the elderly population. Second, the results of trials on the effect of flavor enhancement on liking and intake are described leading to the aims of our studies. Lastly, the outline of the thesis is presented.

THE ELDERLY POPULATION

The world's population is aging. In 2000, the highest percentages of elderly aged 65 and older were found in Europe (16%), North America (13%) and Oceania (10%). By the year 2030 it is expected that these percentages will be one and a half times as high. For other regions such as Africa, the Caribbean and Asia these percentages vary between 3-6% and are expected to double by 2030. Not only is the number of adults older than 65 yrs of age growing but the group of elders also tends to grow older. Thus, the proportion that survives to 80 yrs and beyond is enlarging mainly because of declined mortality rates (US Census Bureau, An Aging World: 2001).

Decline in food intake

The issue of our interest is a decline in food intake with increasing age in both healthy noninstitutionalized and institutionalized elderly people. Data from the NHANES III demonstrates a decrease in energy intake with advancing age in both men and women and by age 80, 1 in 10 men consumed less than 890 kcal/day whereas 1 in 10 women consumed less than 750 kcal/day (Drewnowski and Evans 2001). For many elderly people, the decline in energy intake is greater than the decrease in energy expenditure which points to a negative energy balance, so weight loss occurs (Rolls 2002, Morley 1997). The latter is an important and independent marker of risk of mortality in elderly (Newman et al 2001). Thus, an adequate dietary intake is essential to the enlarging group of elderly to maintain good health (Sullivan 1995, Morley 1997), to reduce overall mortality (Trichopoulou et al 1995, de Groot et al 1996) and to increase the quality of life (Vetta et al 1999).

There are numerous causes for the decline in food intake with aging, which can be categorized into social and environmental causes (de Castro 2002, Walker and Beauchene 1991), psychological (Morley and Silver 1988, Morley 1996) and physiological (Morley 1997).

Some social and environmental causes such as social isolation, no other people present at meals and low income or poverty are negatively associated with intake. Psychological causes include depression, boredom, loneliness and cognitive restraint. Among the physiological factors that negatively affect the regulation of food intake are poor dentition or ill-fitting dentures, a delayed gastric emptying causing an increased antral stretch that could lead to an early satiation (Clarkston et al 1997), the burden of a chronic or acute disease and the presence of arthritis and psychotropic drug use (Payette et al 1995). Another potential cause is the impairment of taste and smell performance. It is often speculated that the decline in taste and in particular smell sensitivity with age (Stevens et al 1984, Murphy 1993, Murphy et al 2002) may affect food perception and alter the enjoyment and palatability of food (Rolls 1999, Schiffman 1993 & 1997). This may lead to a reduced intake in the elderly (Figure 1). However, the sequence of these assumptions is not clear yet (Mattes 2002).

Decline in taste and smell performance

Although people age differently, some changes such as a gradual loss of taste and smell performance affect a great deal of elderly in which the loss of smell is more dramatic than the loss of taste (Stevens et al 1984, Murphy 1993).

Olfactory decline typically begins around 60 yrs of age and becomes more severe in people older than 70 yrs of age (Stevens et al 1984, Murphy 1993, Ship and Weiffenbach 1993, Schiffman 1993 &1997, Murphy et al 2002). The basis of the impairment can be ascribed to changes along the peripheral to the central pathway of the olfactory system (e.g. olfactory epithelium with olfactory receptor neurons, olfactory bulb, anterior olfactory nucleus, olfactory tubercle, amygdala, prepiriform cortex, hippocampus). The terms used to describe a certain degree of loss are anosmia (no sensation of smell), hyposmia (decreased sensation of smell) or dysosmia (distorted smell sensation).

In general, the elderly have higher olfactory detection and identification thresholds for a wide range of odors and mixtures of odors (Schiffman et al 1976, Doty et al 1984) plus they also tend to rate odors as less intense (Murphy 1983, Stevens and Cain 1987). In addition, their ability to discriminate odors (Menashe et al 2003) also seems to be affected. However, the olfactory loss does not apply to all odors (Gilbert and Wysocki 1987) and does not affect all elderly to the same degree. Several studies have confirmed this last part. Forde and Delahunty (2004) studied which of the stimuli taste/smell, texture or irritation would be most dominant in a liking decision for orange juices that were modified using a high and low level of sweetness, pulp, and capsaicin each. Using both young and elderly people they found that about a fourth of the older people preferred the same items as the young group such as low sweetness and low irritation in the juices. The olfactory sensitivity of this particular older group was lower than the young adults but higher compared to the other elderly group. Thus, elderly people could be considered a heterogeneous group when it comes to olfactory functioning as the olfactory performance of some older adults shows overlap with the young adults (Thomas-Danguin et al 2003, Koskinen et al 2003a).

As mentioned before, the taste performance can be affected upon aging but it is difficult to determine to what extent since no drastic physiological changes in the taste system have been observed with aging (Seiberling and Conley 2004). It seems that elderly people have a greater difficulty detecting the presence of sweet, sour, salty, bitter and umami compounds when dissolved in water (Mojet et al 2003) compared to young people. However, it was hard to demonstrate an age effect for the intensity

decrements when the tastants were mixed in with foods (Mojet et al 2003). As for specific taste performance impairment, bitter seems to show the greatest decline with age and sweet perception the least (Murphy and Gilmore 1989). Thus, it seems that the loss in sensitivity is not uniform across the basic tastes.

Causes for a diminished (hypogeusia), altered (dysgeusia) or lost taste perception (ageusia) can be ascribed to peripheral to central changes (from the oral cavity to the neuronal fibers that connect to the brain) that are due to diseases, medication use, treatment and aging (to some extent). However, Mojet et al (2003) found that if tastants are dissolved in water, the age related difference in taste intensity and/or taste liking was much less when subjects wore a nose clip that blocked the olfactory input. This indicates that the decline in taste performance is most likely related to olfactory loss with age.

Decreased sensitivity to a repeated monotonous exposure

Results from nutritional surveys suggest that the dietary variety of in particular institutionalized elderly declines with age (Brown 1976, Fanelli and Stevnhagen 1985). One aspect that may add to the decreased dietary variety is the finding that elderly people are insensitive to a repeated monotonous exposure treatment (Pelchat and Schaefer 2000). Based on early studies one would expect a decrease in acceptance and intake of that food during the repeated monotonous exposure (Siegal and Pilgrim 1958, Schutz and Pilgrim 1958). If there is no decrease in these two aspects due to the insensitivity, this may imply that elderly people are not triggered to seek a wider dietary variety, which could add to dietary inadequacies (Roberts 2000, Bernstein et al 2002).

In practice, a few studies have investigated the effects of a repeated monotonous exposure but some aspects are still unclear. Such as, would the elderly be insensitive to liking and intake when they are repeatedly exposed to common convenience food products that vary in sweetness. Perhaps the finding that on average elderly people prefer higher taste and/or odor concentrations in certain solutions and food products (de Graaf et al 1994, Griep et al 1997, Murphy and Withee 1986, Kozłowska et al 2003, De Jong et al 1996) may adversely affect the insensitivity. Furthermore, what would the effect on liking and intake be if ad libitum consumption is encouraged and if people are in a real life setting instead of in a laboratory? These uncertain aspects led to the study described in **chapter 2** of this thesis. We aimed to investigate whether repeated exposure to ad libitum intake of several fruit drinks varying in sweetness in a real life setting, had an effect on intake, pleasantness and boredom in elderly people.

FLAVOUR ENHANCEMENT

Flavor enhancement in this thesis can be defined as adding a taste compound and/or an odor to a food in order to enhance or intensify its own flavor. With 'flavor of a food' is meant: the distinctive quality of a particular food or drink as perceived with the combined senses of taste and smell. In the studies described in this thesis, either monosodium glutamate (MSG) or a combination of MSG with a flavor (mixtures of odorous molecules extracted from natural products or synthesized) is used.

In 1908 Ikeda isolated glutamate and found its taste clearly distinct from that of the four basic tastes and called it umami meaning brothy, meaty or savory (Lindemann et al 2002, Ikeda 2002). Glutamate (glutamic acid) is the main component of many protein and peptides and is present in most tissues but also in foods such as aged cheese, tomatoes and mushrooms (Table 1). In its free form (not bound to other amino acids in protein) it has a flavor enhancing effect on various foods.

Table 1. Free glutamic acid in food (Ninomiya (1998))

Food	Free glutamic acid (mg/100g)
Cow's milk	2
Cheddar Cheese	182
Parmesan Cheese	1200
Chicken	44
Beef	33
Green asparagus	49
Tomato	246

Monosodium glutamate which is the sodium salt of glutamate, a non-essential amino acid, has a flavor enhancing effect similar to naturally occurring free glutamate (Yamaguchi and Ninomiya 2000). The taste of MSG is not palatable in itself but if added in the right amount, it can enhance the palatability by improving the mouthfulness of foods such meats, poultry, seafood, snacks, soups, stews and starch products (Yamaguchi and Ninomiya 2000). Yamaguchi and Kimizuka (1979) explained mouthfulness as the combined sensation of complex full-body and rich flavor. Regarding its stability, MSG does not decompose during normal food processing or in cooking (Yamaguchi and Ninomiya 1998).

The question whether there are health issues with the use of MSG is briefly addressed here. First, the issue of a surplus of sodium intake while using MSG is a sensitive topic especially in elderly with slower renal function. Contrary to general

belief, MSG is not high in sodium. It contains one third of the amount of sodium as table salt (13 versus 40 percent) plus it is used in smaller amounts. Furthermore, research has shown that the sodium content of soups can be reduced by 40% if 0.6-0.8% MSG is added without influencing the palatability (Altug and Demirag 1993). Thus, MSG can help reduce the total amount of sodium in a recipe. Second, is MSG in foods a trigger for adverse reactions? A large study involving 130 self-identified subjects who believed they reacted to MSG showed that while large amounts of MSG given without food may elicit more symptoms than a placebo, no serious or persistent effects are found when MSG is given with a food (Geha et al 2000).

Flavor enhancement to counteract for the decline in taste and smell performance.

As outlined in Figure 1, the theory to use flavor enhancement to counteract for the decline in taste and smell performance originates from the findings that in general elderly people have a diminished taste and smell performance (Stevens et al 1984, Murphy 1993) and that they prefer a higher taste and/or odor concentration in certain solutions and food products (Murphy and Withee 1986, De Graaf et al 1994, De Graaf et al 1996, De Jong et al 1996, Griep et al 1997, Kozłowska et al 2003). In some early studies, the preference for food with extra flavor (mixtures of odors) led to an increased intake among hospitalized elderly (Schiffman and Warwick 1988 & 1989) hence it was suggested that flavor enhancement is useful to make up for the diminished taste and smell performance.

The issue with the above described studies is that the taste and smell performance is not measured in their population. To properly investigate the theory that flavor enhancement compensates for the decline in taste and smell performance, it should be tested in an elderly population in which the taste and smell status has been assessed with the use of chemosensory performance tests. If flavor enhancement has a compensatory function, the results would indicate that those elderly with an impaired taste and smell performance prefer flavor-enhanced food to non-enhanced food.

There are some studies that did measure the performance of taste and/or smell but these found either no or mixed results when trying to relate the sensory functioning to a higher liking of flavor-enhanced foods. Koskinen et al (2003b) measured odor detection and identification functioning and found that, despite impaired olfactory capabilities, pleasantness ratings and intake of elderly participants (63-85 yrs) did not increase upon consumption of a yoghurt-like product with extra red currant aroma. Forde and Delahunty (2004) found mixed results regarding the

relationship between sensory functioning and hedonic responses within a group of elderly participants. They measured the sensitivity of taste, smell, irritation and texture perception in young (n=48, 20-50 yrs) and elderly people (n= 52, >65 yrs) to test which of the stimuli would be most dominant in a liking decision for modified orange juices (high and low level of sweetness, pulp, and capsaicin each). Their results show that one subgroup of elderly (O1) had lower sensory perception than the other (O2) and they preferred the higher level of sensory stimulation. However, the other group (O2) also with low sensory perception liked the lower level of sensory stimulation in the juices just as the younger population. Thus, the results obtained by these studies are not completely clear, despite the assessed taste and/or smell functioning.

Therefore, additional information is needed to verify the relationship between a low taste and/or and smell performance and a higher liking of flavor-enhanced food in elderly people. **Chapter 3** illustrates the effect of soup enhanced with MSG and celery powder against non-enhanced soup on liking and intake in elderly people with a diminished taste and/or smell performance. A small part of **chapter 5** describes the relationship between olfactory performance and pleasantness ratings in young and in institutionalized elderly people.

Flavor enhancement as an approach to increase liking and the optimal amount

When it comes to flavor enhancement as an approach to increase the palatability of food, few studies find an effect in elderly (Schiffman and Warwick 1989) that were either hospitalized (Griep 1997), free living (Griep 2000), living a retirement home (Schiffman 1998) or had poor nutrition status (Murphy 1987) (Table 2). The last study found that the elderly preferred a higher MSG concentration than young people when using a MSG range from 0-0.5% in soup. In contrast to these findings, Koskinen et al (2003b) did not find a positive effect of flavor enhancement on liking in the elderly. Due to this inconsistency, more data is necessary to verify the effect of flavor enhancement on intake. The effect of flavor enhancement on liking is described in **chapter 3** where elderly people received soup enhanced with MSG and celery powder and in **chapter 4** where we studied the effect of MSG and/or flavors added to the hot meal of nursing home elderly.

Table 2. Overview of several studies investigating the effect of flavor enhancement on food palatability and/or food intake in elderly people

Author	Subjects	Flavor enhancement	Added to	Procedure	Effect
Bellisle et al 1991	N=65 Elderly	MSG 0.6%, determined in young subjects	2 lunch menus (A + B) containing a soup and vegetable dish.	6 blocks. First 3: A: MSG-, B: MSG+. Last 3: A: MSG+ B: MSG-. Intake measured	On intake: MSG caused increased intake of one soup and of mashed potatoes, but not of another soup and cooked rice. Total energy intake remained stable because of less intake of non MSG containing foods
Griep et al 1997	N=16 20-30 yrs N=20 >60 yrs	Vegetable flavor Chicken flavor/ marjoram Cherry flavor	Soup Meat substitute Yogurt	Two testing days, 3 foods with high and low flavor in random order	On preference: roughly half of the elderly had no preference for either high or low flavor level. The other half preferred the high level. On intake: elderly consumed more high and low flavored soup and more of high flavored yoghurt than the young
Griep et al 2000	N=260 19-98 yrs N=120 20-90 yrs	Chicken flavor/ marjoram Strawberry flavor	Meat substitute Yoghurt	Tasting session: 2 samples high and low flavor in random order Intake test: 400 g ad libitum yoghurt (either high or low flavor)	On preference: for both foods, the percentage of people preferring the high flavor levels, increased with age. On intake: relative consumption of high flavored yoghurt was not correlated with age
Koskinen et al 2003b	N=58 18-34 yrs N=50 63-85 yrs	Currant aroma	Red berry-flavored fermented oat bran product	Two test sessions of product with high and regular flavored	On preference: pleasantness ratings for both flavors merged during exposure On intake: elderly did not consume more of high flavored food

Author	Subjects	Flavor enhancement	Added to	Procedure	Effect
Mathey et al 2001	N=31 83 yrs control group N=36 84.6 yrs flavor group	Flavors+ MSG (0.3%): chicken, beef, turkey, lemon butter	Cooked meal	16-week parallel group intervention Intake measured before, during and after intervention	On intake: intake of the cooked meal increased in the flavor group, not in control. No increase of daily dietary intake in flavor group
Murphy 1987	N=7 18-26 yrs N=21 >65 yrs	MSG: 0-0.1-0.2-0.3-0.4-0.5%	Soup	Pleasantness scores	On preference: Elderly and people with poor nutritional status preferred higher MSG concentrations than young subjects and people with high nutritional status
Schiffman 1988	N=? 70-79 yrs	Flavors: carrot, bacon, pea, potato, tomato, chicken, apple	Vegetables, meats, soups, juice	Three food samples: 1 enhanced, 2 not enhanced Liking was assessed	On preference: 75.5% of the subjects preferred an enhanced sample The rest preferred the unflavored sample
Schiffman 1993	N=39 84.6 yrs	Flavors: roast beef, ham, natural bacon, prime beef, maple, cheese	Soups, gravies, eggs, vegetables, grits, stews, sauces, oatmeal, macaroni	Two 3-weeks period, one with enhanced food, one with unenhanced foods. 1 or 2 foods were enhanced at each meal	On intake: increase in intake but significant for 3 out of 20 foods only

Author	Subjects	Flavor enhancement	Added to	Procedure	Effect
Schiffman 1994	N=14 23.8 yrs N=10 87.5 yrs	Young: 0.004-4.421% in 1.5 mL, added to 5 g. food Elderly: 0.017-4.421% 0.6 log steps. (With/without 0.5mM IMP)	Carrots, corn, peas, chicken broth, onion soup, tomato soup, cubed steak, ground turkey, ground chicken	Given to young and elderly. Ratings for liking, strong taste, sweetness, sourness, saltiness, bitterness and umami taste	On preference: no clear relationship between MSG concentration and preference ratings. Elderly gave lower intensity ratings of MSG than young
Schiffman 1998	N=43 elderly Malnourished/ 6% weight loss/low weight for height+ age	Determined in pre-testing 0.3-1.0% (exact concentrations not given) + 5'nucleotides + flavors	Foods (<i>unclear which foods</i>)	Clinical setting. Food intake, plasma proteins and weight measured	On intake: combination of MSG and flavors: 10% increase in energy intake compared to no MSG and flavors in most patients. In some patients also improved plasma proteins. Also weight gain observed
Schiffman 1998	N=50 81.7 yrs	Determined in pre-testing 0.3-1.0% (exact concentrations not given) + flavors	Meats, soups, gravies, sauces, vegetables, grits, eggs and egg substitutes and macaroni	Group 1: 4 weeks: MSG-, 4 weeks: MSG+. Group 2: reversed. Satisfaction ratings. T+ B cells + anthropologically	MSG + flavors improved acceptability of foods compared to foods without MSG and flavor addition. Small increase in T and B cells and handgrip strength.

Author	Subjects	Flavor enhancement	Added to	Procedure	Effect
Schiffman and Miletic 1999	N=10 25.1 yrs N=10 69.5 yrs	Young and elderly: Corn: 0.3, 3.5% Carrots: 0.15, 2.0% Chicken broth: 0.6, 2.0% Onion soup: 0.8, 1.5%	Corn, carrots, chicken broth and onion soup	Test foods with and without MSG. Saliva collected 4 times	Elderly had an increased salivary IgA secretion rate after consumption of foods with MSG compared to foods without. Preferred MSG concentration in foods were higher in elderly

As mentioned earlier, the effect of MSG on palatability of various foods seems to be concentration specific meaning that the optimal concentration of MSG differs between the food products (Yamaguchi and Takahashi 1984). A study by Schiffman and Miletic (1999) shows different optimal MSG concentrations for several foods plus an age related effect between these optimal amounts. They found that the optimal MSG concentrations for the elderly varied between 1.5% -3.5% for onion soup, chicken broth, carrots and corn and in addition, these concentrations were at least 10 times higher for the elderly than for the young. To confirm the finding that the optimal preferred MSG concentrations in various food items differs and if this is age related, the first part of the two-fold study reported in **chapter 5** aimed to obtain the optimal MSG concentration for some common foods in young and institutionalized elderly people.

Flavor enhancement as an approach to increase intake

On the one hand, studies using MSG by Bellisle et al (1991) and Schiffman (1998) and Schiffman and Warwick (1993) (Table 2) show a weak indication that flavor enhancement increases intake in hospitalized or institutionalized elderly. In the first study, the intake of selected food increased but the total meal intake was not affected. The last study found an increased intake of 3 out of 20 flavor-enhanced foods. Furthermore, these studies were relatively short term (6 non-consecutive test days within 6 months to 4 weeks). On the other hand, one long-term trial of 16 weeks by Mathey et al (2001) showed that dietary intake of the flavor-enhanced meal increased after repeated consumption and that daily energy intake remained relatively stable. The daily energy intake of the control group declined. The inconsistent results between these studies could possibly be explained by the study duration.

In summary, the effect of a short-term flavor enhancement treatment on intake is not pronounced whereas the long-term approach does point out its potential to increase the intake of flavor-enhanced foods. Since the long-term effect was not clearly present on daily energy intake, additional data is needed to confirm the long-term effect of flavor enhancement. **Chapter 4** evaluates whether there is a long-term effect of MSG and/or flavors on dietary intake and nutritional status of institutionalized elderly. The second part of **Chapter 5** addresses whether an optimal preferred MSG concentration in several foods increases intake in institutionalized elderly people.

OUTLINE OF THESIS

The main objectives of this thesis are to investigate the effect of flavor enhancement (adding a taste compound and/or an odor to a food in order to enhance or intensify its own flavor) on food intake in elderly people and the relationship between an altered taste and smell performance and liking of flavor-enhanced foods. Table 3 presents the formulated research questions to study these objectives.

Table 3. Outline of this thesis

Chapter	Research question
2	What is the effect of repeated exposure to fruit drinks with different sweet intensities on the intake, pleasantness and boredom in young and noninstitutionalized elderly adults?
3	What is the effect on intake and liking of soup enhanced with MSG and celery powder vs non-enhanced soup among noninstitutionalized elderly with olfactory and gustatory loss?
4	What is the long-term effect (16 weeks) of flavor enhancement (MSG and/or flavors) on dietary intake, pleasantness and nutritional status of nursing home elderly?
5	A two-fold study: 1a) What the optimal preferred MSG concentration is in common foods that make up a hot meal for young and institutionalized elderly people? 1b) Is there a relationship between olfactory performance and pleasantness ratings in young and in institutionalized elderly people? 2) What is the effect of the obtained optimal MSG concentrations in the foods on intake among institutionalized elderly people?

Lastly, **chapter 6** presents the general discussion that includes the main findings, reflections, a proposed future strategy and the conclusion.

REFERENCES

- Altug T, Demirag K. Influence of monosodium glutamate on flavor acceptability and on the reduction of sodium chloride in some ready-made soups. *Chem Mikrobiol Technol Lebensmittel* 1993;15:161-164
- Bellisle F, Dalix AM, Chappuis AS, Rosi F, Fiquet P, Gaudin V, Assoun M, Slama G. Monosodium glutamate affects mealtime food selection in diabetic patients. *Appetite* 1996;26:267-275
- Bellisle F, Monneuse MO, Chabert M, Larue-Achagiotis C, Lanteaume MT, Louis-Sylvestre J. Monosodium glutamate as a palatability enhancer in the European diet. *Physiol Behav* 1991;49:869-873
- Bernstein MA, Tucker KL, Ryan ND, O'Neill EF, Clements KM, Nelson ME, et al Higher dietary variety is associated with better nutritional status in frail elderly people. *J Am Diet Assoc* 2002;102:1096–1104
- Brown EL. Factors influencing food choices and intake. *Geriatrics* 1976;31:89–92
- Clarkston WK, Pantano MM, Morley JE, Horowitz M, Littlefield JM, Burton FR. Evidence for the anorexia of aging: gastrointestinal transit and hunger in healthy elderly vs young adults. *Am J Physiol* 1997;272:R243-248
- De Castro JM. Age-related changes in the social, psychological, and temporal influences on food intake in free-living, healthy, adult humans. *J Gerontol A Biol Sci Med Sci* 2002;57:M368-377
- De Graaf C, Polet P, van Staveren WA. Sensory perception and pleasantness of food flavors in elderly subjects. *J Gerontol* 1994;49:P93-99
- De Graaf C, van Staveren W, Burema J. Psychophysical and psychohedonic functions of four common food flavors in elderly subjects. *Chem Senses* 1996;21:293-302
- De Groot LC, van Staveren WA, Burema J. Survival beyond age 70 in relation to diet. *Nutr Rev* 1996;54:211-212
- De Jong N, De Graaf C, Van Staveren WA. Effect of sucrose in breakfast items on pleasantness and food intake in the elderly. *Physiol Behav* 1996;60:1453-1462
- Doty RL, Shaman P, Applebaum SL, Giberson R, Siksorski L, Rosenberg L. Smell identification ability: changes with age. *Science* 1984;226:1441-1443
- Drewnowski A, Evans WJ. Nutrition, physical activity, and quality of life in older adults: summary. *J Gerontol A Biol Sci Med Sci* 2001;56:89-94
- Fanelli MT, Stevenhagen KJ. Characterizing consumption patterns by food frequency methods: core foods and variety of foods in diets of older Americans. *J Am Diet Assoc* 1985;85:1570–1576
- Ferris AM, Duffy VB. Effect of olfactory deficits on nutritional status. Does age predict persons at risk? *Ann N Y Acad Sci* 1989;561:113-123
- Forde CG, Delahunty CM. Understanding the role cross-modal sensory interactions play in food acceptability in younger and older consumers. *Food Qual Prefer* 2004;5:715-727

Chapter 1

Geha RS, Beiser A, Ren C, Patterson R, Greenberger PA, Grammer LC, Ditto AM, Harris KE, Shaughnessy MA, Yarnold PR, Corren J, Saxon A. Multicenter, double-blind, placebo-controlled, multiple-challenge evaluation of reported reactions to monosodium glutamate. *J Allergy Clin Immunol* 2000;106: 973-980

Gilbert AN, Wysocki CJ. National Geographic smell survey: The results. *National Geographic* 1987;122:514-525

Griep MI, Mets TF, Massart DL. Different effects of flavour amplification of nutrient dense foods on preference and consumption in young and elderly subjects. *Food Qual Prefer* 1997;8:151-156

Griep MI, Mets TF, Massart DL. Effects of flavor amplification of Quorn and yoghurt on food preference and consumption in relation to age, BMI and odour perception. *Br J of Nutr* 2000;83:105-113

Ikeda K. New seasonings. *Chem Senses* 2002;27:847-849

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

Koskinen S, Kalviainen N, Tuorila H. Perception of chemosensory stimuli and related responses to flavored yogurts in the young and elderly. *Food Qual Prefer* 2003a;14:623-635

Kozłowska K, Jeruszka M, Matuszewska I, Roszkowski W, Barylko-Pikielna N, Brzozowska A. Hedonic tests in different locations as predictors of apple juice consumption at home in elderly and young subjects. *Food Qual Prefer* 2003;14:653-661

Lindemann B, Ogiwara Y, Ninomiya Y. The discovery of umami. *Chem Senses* 2002;27:843-844

Mathey MAM, Siebelink E, De Graaf C, van Staveren WA. Flavor enhancement of food improves dietary intake and nutritional status of elderly nursing home residents. *J Gerontol A Biol Sci Med Sci* 2001;56A:M200-M205

Mattes R. The chemical senses and nutrition in aging: Challenging old assumptions. *J Am Diet Assoc* 2002;102:192-196

Menashe I, Man O, Lancet D, Gilad Y. Different noses for different people. *Nat Genet* 2003;34:143-144

Mojet J, Heidema J, Christ-Hazelhof E. Taste perception with age: generic or specific losses in supra-threshold intensities of five taste qualities? *Chem Senses* 2003;28:397-413

Morley JE, Silver AJ. Anorexia in the elderly. *Neurobiol Aging* 1988;9:9-16

Morley JE. Anorexia in older persons: epidemiology and optimal treatment. *Drugs Aging* 1996;8:134-155

Morley JE. Anorexia of aging: Physiologic and pathologic. *Am J Clin Nutr* 1997;66:760-773

Murphy C, Gilmore MM. Quality-specific effects of aging on the human taste system. *Percept Psychophys* 1989;45:121-128

Murphy C, Schubert CR, Cruickshanks KJ, Klein BEK, Klein R, Nondahl DM. Prevalence of Olfactory Impairment in Older Adults. *JAMA* 2002;288:2307-2312

- Murphy C, Withee J. Age-related differences in the pleasantness of chemosensory stimuli. *Psychol Aging* 1986;1:312-318
- Murphy C. Age-related effects on the threshold, psychophysical function, and pleasantness of menthol. *J Gerontol* 1983;38:217-22
- Murphy C. Flavor preference for monosodium glutamate and casein hydrolysate in young and elderly persons. *Umami: A basic taste*, 1987 pp139-151. Marcel Dekker, New York, USA
- Murphy C. Nutrition and chemosensory perception in the elderly. *Crit Rev Food Sci Nutr* 1993;33:3-15
- Newman AB, Yanez D, Harris T, Duxbury A, Enright PL, Fried LP. Weight change in old age and its association with mortality. *J Am Geriatr Soc* 2001;59:1309-1318
- Ninomiya K. Natural occurrence. *Food Rev Int* 1998;14:177-211
- Payette H, Gray-Donald K, Cyr R, Boutier V. Predictors of dietary intake in a functionally dependent elderly population in the community. *Am J Public Health* 1995;85:677-683
- Pelchat ML, Schaefer S. Dietary monotony and food cravings in young and elderly adults. *Physiol Behav* 2000;68:353-359
- Roberts SB. Energy regulation and aging: recent findings and their implications. *Nutr Rev* 2000;58:91-97
- Rolls BJ. Aging and appetite. *Nutr Rev* 1992;50:422-426
- Rolls BJ. Do chemosensory changes influence food intake in the elderly? *Physiol Behav* 1999;66:193-197
- Schiffman SS, Miletic IDJ. Effect of taste and smell on secretion rate of salivary IgA in elderly and young persons. *J Nutr Health Aging* 1999;3:158-164
- Schiffman SS, Moss J, Erickson RP. Thresholds of food odors in the elderly. *Exp. Aging Res* 1976;2:389-398
- Schiffman SS, Sattely-Miller EA, Zimmerman IA, Graham BG, Erickson RP. Taste perception of monosodium glutamate (MSG) in foods in young and elderly subjects. *Physiol Behav* 1994;56:265-275
- Schiffman SS, Warwick ZS. Effect of flavor enhancement of foods for the elderly on nutritional status: Food intake, biochemical indices, and anthropometric measures. *Physiol and Behav* 1993;53:395-402
- Schiffman SS, Warwick ZS. Flavor enhancement of foods for the elderly can reverse anorexia. *Neurobiol of Aging* 1988;9:24-26
- Schiffman SS, Warwick ZS. Use of flavor-amplified foods to improve nutritional status in elderly patients. *Ann N Y Acad Sci* 1989;561:267-276
- Schiffman SS. Perception of taste and smell in elderly persons. *Crit Rev Food Sci and Nutr* 1993;33:17-26
- Schiffman SS. Sensory enhancement of foods for the elderly with monosodium glutamate and flavors. *Food Rev Int* 1998;14:321-333

Chapter 1

- Schiffman SS. Taste and smell loss in normal aging and disease. *JAMA* 1997;278:1357-1362
- Schutz HG, Pilgrim FJ. A field study of food monotony. *Psychol Rep* 1958;4:559–565
- Seiberling KA, Conley DB. Aging and olfactory and taste function. *Otolaryngol Clin North Am* 2004;37:1209-1228
- Ship JA, Weiffenbach JM. Age, gender, medical treatment, and medication effects on smell identification. *Gerontol A Biol Sci Med Sci* 1993;48:M26-32
- Siegal PS, Pilgrim FJ. The effect of monotony on the acceptance of food. *Am J Psychol* 1958;71:756–759
- Stevens JC, Bartoshuk LM, Cain WS. Chemical senses and aging: taste versus smell. *Chem Senses* 1984;9:167-179
- Stevens JC, Cain WS. Old-age deficits in the sense of smell as gauged by thresholds, magnitude matching, and odor identification. *Psychol Aging* 1987;2:36-42
- Sullivan DH. Impact of nutritional status on health outcomes of nursing home residents. *J Am Geriatr Soc* 1995;43:195-196
- Thomas-Danguin T, Rouby C, Sicard G, Vigouroux M, Farget V, Johanson A, Bengtson A, Hall G, Ormel W, De Graaf C, Rousseau F, Dumont JP. Development of the ETOC: a European test of olfactory capabilities. *Rhinology* 2003;41:142-151
- Trichopoulos A, Kouris-Blazos A, Wahlqvist ML, Gnardellis C, Lagiou P, Polychronopoulos E, Vassilakou T, Lipworth L, Trichopoulos D. Diet and overall survival in elderly people. *BMJ* 1995;311:1457-1460
- US Census Bureau, Series P95/01-1, An Aging World: 2001. Kinsella K, Velkoff V. Washington, DC, 2001
- Vetta F, Ronzoni S, Taglieri G, Bollea MR. The impact of malnutrition on the quality of life in the elderly. *Clin Nutr* 1999;18:259-267
- Walker D, Beauchene RE. The relationship of loneliness, social isolation, and physical health to dietary adequacy of independently living elderly. *J Am Diet Assoc* 1991;91:300-304
- Yamaguchi S, Kimizuka A. Psychometric studies on the taste of monosodium glutamate. In: *Glutamic Acid: Advances in Biochemistry and Physiology*. Filer LJ Jr, Garattini S, Kare M R, Reynolds WA, Wurtman R J, eds. 1979 pp 35–54. Raven Press, New York, USA
- Yamaguchi S, Ninomiya K. Umami and food palatability. *J Nutr* 2000;130:921S-926S
- Yamaguchi S, Ninomiya K. What is umami? *Food Rev Int* 1998;14:123-138
- Yamaguchi S, Takahashi C. Hedonic functions of monosodium glutamate and four basic taste substances used at various concentration levels in single and complex systems. *Agric Biol Chem* 1984;48:1077-1081

2

The effect of repeated exposure to fruit drinks on intake, pleasantness and boredom in young and elderly adults

Natasja H Essed • Wija A van Staveren • Frans J Kok • Wieke Ormel • Gertrude Zeinstra • Cees de Graaf • **Physiol Behav 2006;89:335-341**

ABSTRACT

The effect of a repeated monotonous exposure on ad libitum intake, pleasantness and boredom in elderly people in a real life situation is unclear. We therefore investigated the effects of repeated exposure to ad libitum intake of three orange-based drinks on boredom and acceptance in young and elderly people. Young (n=32) and elderly women (n=36) participated in a randomized within subjects cross over trial with three intervention periods of 12 days each followed by a 2-day wash out period. During each intervention period, the participants received 1 L of one type of drink per day. The three drinks varied in sweetness intensity. Intake was measured by weighing the returned packets and pleasantness, boredom and sweetness were rated on a 10-point scale. For the young women, mean consumption of the three drinks ($p<0.01$) and pleasantness decreased ($p<0.01$) and boredom increased ($p<0.001$). For the elderly women, consumption increased ($p=0.03$) whereas pleasantness ($p=0.34$) and boredom ($p=0.40$) were stable. In the young women, the orange peach drink which had the highest sugar content contributed the most to the effect of the repeated exposure. The consumption and pleasantness ratings for this drink decreased ($r=-1.05$, $p=0.01$ and $r=-0.07$, $p=0.007$, respectively) and boredom increased ($r= 0.12$, $p< 0.001$). Elderly women experienced no increased boredom whereas young women did.

INTRODUCTION

Most elderly people deal with a gradual loss of taste and smell perception as part of a physiological ageing process (Ship and Weiffenbach 1993, Schiffman 1993) by which the loss of smell is greater than the loss of taste (Stevens et al 1984, Murphy 1993). Because taste and smell are crucial determinants of the palatability of foods (Rolls 1993), this dysfunction could be associated with diminished enjoyment of food (Rolls 1999). This may result in a lower appetite and food intake (Morley 1997).

A related issue is that sensory-specific satiety diminishes with ageing (Rolls and McDermott 1991) which is defined as a decrease of the pleasantness of the sensory properties of an eaten food compared to an uneaten food (Hetherington et al 1989, Rolls et al 1983). A decreased sensitivity for sensory-specific satiety could be associated with the consumption of a monotonous diet (Rolls 1993).

Early studies on the effects of a monotonous exposure showed a decrease in acceptance and intake of that food during that time (Siegal and Pilgrim 1958, Schutz and Pilgrim 1958). This does not occur for all foods equally, mainly because the effects of a repeated exposure depend on several factors such as the initial level of liking of a food, the overall variety of the diet, the exposure to novel tastes, the duration of exposure and the consumption of savory or sweet foods (Siegal and Pilgrim 1958, Schutz and Pilgrim 1958, Pliner 1982).

Data from nutritional surveys suggest that dietary variety declines with age, especially in institutionalized persons (Brown 1976, Fanelli and Stevenhagen 1985.). Apart from the loss of taste and smell and diminished sensory-specific satiety, this may also be related to the finding that elderly are insensitive to a monotonous diet (Pelchat and Schaefer 2000). As a consequence, elderly people are not triggered to seek a wider dietary variety which could therefore contribute to dietary inadequacies (Roberts 2000, Bernstein et al 2002).

To our knowledge, there is one study on the effect of repeated exposure to one particular food in elderly people. Pelchat and Schaefer (2000) studied the effect of a fixed amount of a vanilla-flavored beverage on the pleasantness and intake in young and elderly people at baseline and after a period of repeated monotonous exposure, where participants had access to the vanilla beverage only. The young adults reported significantly more cravings per day during the monotonous period compared to the baseline period. In contrast, elderly people did not report an increase in cravings during the monotonous period. Therefore, it was hypothesized that the elderly were insensitive to the repeated monotonous exposure manipulation.

The effects of a repeated monotonous exposure to common, convenience food products on the development of boredom in elderly people are unknown. Therefore, this study examined whether 12 days of monotonous repeated exposure to ad libitum intake of three orange-based drinks has an effect on consumption, pleasantness and boredom in young and elderly people with no diet restrictions in a real life setting.

PARTICIPANTS AND METHODS

The study included 33 young women and 36 elderly women. Participants were recruited by displaying posters in and around Wageningen University and in clubs for the elderly. All participants were screened before enrollment to ensure that they were healthy, independently living, non-reported diabetic, non-restraint eaters (score for restraint eaters on restraint scale of the DEBQ < 2.8), non obese (BMI ≤ 30 kg/m²) and liked orange-based drinks. The inclusion criteria for age were 18 to 30 years for the young women and 65 years and older for the elderly women. Each participant signed an informed consent form prior to the start of the study and was paid for participation at the end of the study. 36 older women and 32 young women completed the study successfully (Table 1). One young woman withdrew from the study because of personal reasons. The study protocol and all the material provided to the participants was approved by the Medical Ethical Review Committee of the Division of Human Nutrition of Wageningen University.

Table 1. Characteristics of the young and elderly female participants (mean ± SD)

Characteristics	Young female (n = 32)	Elderly female (n = 36)
Age (year)	21.0 ± 1.9	73.5 ± 5.4
Weight (kg)	64.9 ± 7.9	72.0 ± 9.5
Height (m)	1.72 ± 0.1	1.63 ± 0.1
BMI (kg/m ²)	22.0 ± 2	27.2 ± 4
Score on restrained scale of DEBQ (<2.8)	2.15 ± 0.4	2.16 ± 0.7

Design

The study consisted of a 1-week laboratory period in which a sensory profile of the three drinks was obtained followed by a 6-week intervention period. The 6-week intervention period consisted of a cross over design with three 12-day intervention periods which were followed by a wash out period of 2 days. During each intervention period, participants received 1 L daily of one type of an orange-based drink for 12 consecutive days. The order of the three orange-based drinks was randomly assigned to each subject.

Stimuli

The drinks used in this study were orange mandarin drink, orange juice and orange peach drink (RiedelDrinks, Ede, The Netherlands). Their Dutch brand names were as follows: Dubbelfris, Appelsientje and Dubbeldrank, respectively. Since various studies showed that elderly have higher optimal preferred flavor concentrations in foods items than younger people (Murphy and Withee 1986 & 1987, Zallen et al 1990, De Graaf et al 1994 & 1996, De Jong et al 1996), the three orange-based drinks were selected because they differed in sweetness intensity. The orange mandarin drink was targeted for young people because it has a less intense sweet taste. The orange peach drink was targeted for the elderly people because of its higher sugar content, and orange juice was for all age groups. All the drinks were familiar to the participants. Table 2 shows the macronutrient composition of the fruit drinks.

Table 2. Macronutrient composition of the 3 orange based drinks per 100 mL

Component	Orange mandarin drink	Orange juice	Orange peach drink
Energy (kJ)	167	172	230
(kcal)	40	41	55
Protein (g)	0.1	0.6	0.3
Fat (g)	0	0	0
Total carbohydrate (g)	9.5	9.3	13.1
- Saccharose (g)	7.9	4.0	9.8
- Glucose (g)	0.6	2.6	1.6
- Fructose (g)	1.0	2.7	1.7
Fruit content (%)	20	100	50
Added sugar (g)	7.9	-	9.8

The packing material of all drinks was blank in order to guarantee a single blind trial. All drinks presented to the participants were from the same processing batch and were also commercially available in supermarkets at the time of the study.

Procedure

Within the laboratory period, all participants came to the laboratory where they were instructed on how first to rate pleasantness and then perceived sweetness, sourness, fullness, freshness, watery, viscosity, mildness and sharpness of the three orange-based drinks on a 10-point scale (Table 3). The anchors of the scales were explained as “not at all” (left anchor=1) to “extremely” (right anchor=10) pleasant, sweet, sour, full, fresh, watery, viscous, mild and sharp. The participants were asked not to eat, drink or brush their teeth within one hour before coming to the laboratory. All drinks were presented in sensory booths. Each time, 50 mL of the drink was served in a plastic cup at room temperature. Participants used the sip and swallow method to

judge the products (Zandstra et al 1999). After each drink, participants had to neutralize their senses with water and a cracker. The drinks were presented in random order.

Table 3. Mean ratings (SD) on a 10-point scale of the attributes for the three orange based drinks rated by 32 young and 36 elderly women

Attributes	Orange mandarin drink		Orange juice		Orange peach drink	
	Young	Old	Young	Old	Young	Old
Pleasantness	5.1 (2.1) ^A	5.2 (2.6) ^D	7.0 (1.9) ^B	6.5 (2.1) ^E	7.6 (1.3) ^B	7.2 (2.3) ^E
Sweetness	6.9 (2.1) ^A	5.3 (2.6) ^D	5.0 (2.4) ^B	4.6 (2.3) ^D	8.0 (1.3) ^A	7.8 (1.5) ^E
Sourness	5.1 (2.2) ^A	4.3 (2.6) ^D	6.8 (2.2) ^B	4.6 (2.6) ^D	3.1 (1.7) ^C	2.2 (1.5) ^E
Fullness	4.3 (2.3) ^A	4.1 (2.5) ^D	7.4 (1.3) ^B	6.1 (2.4) ^E	8.4 (1.3) ^B	7.3 (2.0) ^E
Freshness	6.9 (1.7) ^A	5.9 (2.7) ^D	6.2 (2.2) ^{A,B}	6.5 (2.0) ^D	5.3 (1.9) ^B	5.6 (2.2) ^D
Watery	6.5 (2.3) ^A	5.5 (2.7) ^D	3.1 (1.9) ^B	3.4 (2.1) ^E	2.4 (1.5) ^B	2.4 (1.5) ^E
Viscosity	2.6 (1.8) ^A	1.7 (1.2) ^D	4.3 (2.4) ^B	2.5 (1.9) ^D	6.7 (2.1) ^C	4.6 (2.7) ^E
Mildness	4.3 (1.6) ^A	3.9 (2.1) ^D	3.8 (1.7) ^A	4.8 (2.1) ^D	5.9 (1.9) ^B	6.4 (1.8) ^E
Sharpness	5.5 (2.4) ^A	4.3 (3.2) ^D	6.5 (2.2) ^A	4.9 (2.7) ^D	3.3 (2.1) ^B	3.1 (2.4) ^D

Values in the same row with different superscript letters are significantly different for ^{A,B,C} the young women and ^{D,E,F} the elderly women, $p < 0.05$ (Tukey's HSD test)

The 6-week intervention period was an in home test. The packets of drink were either collected at the laboratory twice a week or delivered to the homes of those participants that were unable to come. The participants received 1 L of a drink for each day and were instructed to use a new pack of drink every day. Each pack was coded with a product number, the date of use and the number of the subject. They were encouraged to drink as much as they wished, but least one glass a day. Participants were requested not to share their drink with others and to store all the opened packs with the remainder of the drink in the refrigerator and to save the empty ones. All the packs were returned to the laboratory upon collecting the new packs.

The opened packs of drink that were returned to the laboratory were weighted on an electrical weighing scale (Sartorius, 1203 MP, Goettingen, Germany) to the nearest gram. The amount of drink that each subject had drunk on a day was calculated by subtracting the weight of the opened pack with the leftover from the mean weight of a full packet of that same drink. This mean was calculated by measuring the total weight of five full packs and dividing it by 5. For orange mandarin drink, orange juice, orange peach drink the average content was 1076 g, 1073 g and 1087 g, respectively.

Once a day after drinking, the pleasantness, sweetness and boredom of the taste of the product were rated on a 10-point scale. The anchors of the scales were explained from “not at all” to “extremely” pleasant, sweet and bored. At the end of each day participants completed a health and medication questionnaire about experienced health problems and their use of medications on that day. It also included questions about the amount of physical activity performed, whether it was less, the same or more than average.

Statistics

One-way ANOVA was used to analyze the differences between the mean ratings per attribute for three orange-based drinks for the sensory profile. The ratings on attributes were the dependent variables and the drink type was the independent variable. Post hoc comparisons between the mean ratings per attribute for the three drinks were carried out using Tukey's HSD test.

To evaluate changes for the amount consumed and the attributes ratings over 12 days, individual-level regression analysis were performed. First, the individual slopes for each attribute were calculated across the three drinks together for both age groups separately. Then, the difference between the mean slopes for both age groups was tested with an independent t-test. ANOVA was used to test differences between the mean slopes for each of the three fruit drinks per age group. The ratings of the attributes were used as dependent variables and the variable day was used as independent variable.

All statistical analyses were performed with SPSS for WINDOWS software (version 11.5; SPSS Benelux, Gorinchem, The Netherlands). p values <0.05 were considered significant.

RESULTS

None of the participants reported health problems during the study. Of all the packs 98% was brought back to the laboratory and weighted. Compliance of intake was high. Sixteen out of the 68 participants shared their pack of drink once or twice but that represented less than 1% of the total packs that were distributed among the participants. The amount shared was negligible and we therefore included these participants in our data analysis.

Sensory profile of the three orange-based drinks

Although there were some absolute differences in the ratings of the attributes for the young and the elderly people, the rank orders of the ratings of the attributes were

similar for the two groups except for the attributes freshness and mildness (Table 3). Both age groups perceived the orange peach drink as the sweetest, fullest, mildest, thickest and most pleasant drink. Orange juice was perceived as the least sweet and orange mandarin drink was rated as the least pleasant.

Changes after 12 days for the young and the elderly in the amount consumed and sensory/motivational ratings for the three orange-based drinks together

The young group showed a significance decrease in consumption from 0.50 L on day 1 to 0.38 L on day 12 ($p=0.002$) (Table 4 and Figure 1). The elderly group increased their consumption from 0.49 L to 0.56 L ($p=0.03$). The change in consumption over 12 days was different for the young and the elderly participants ($T=-4.5$, $p<0.001$).

The pleasantness ratings for the young decreased from 7.0 on day 1 to 6.3 on day 12 ($p=0.002$) whereas the ratings for the elderly did not change ($p=0.34$). Comparing the mean slopes for the age groups showed that the slope for the elderly is different from the descending slope for the young participants ($T=-3.2$, $p=0.002$). The young showed an increase in boredom ratings from 3.3 on day 1 to 4.9 on day 12 ($p<0.001$) but no increase in boredom ratings was seen within the elderly group ($p=0.40$). The change in boredom ratings over 12 days differed between the young and elderly women ($T=3.8$, $p<0.001$). The sweetness ratings for the young ($p=0.05$) and the elderly group ($p=0.8$) did not change.

Table 4. Mean slopes (SD) and p values representing the change per day for the amount consumed, pleasantness, boredom and sweetness for the 3 fruit drinks together during 12 days for the young and the elderly women.

Attribute	Young (n=32)	Elderly (n=36)
Amount consumed %	-0.74 (0.24) $p=0.002$	0.47 (0.22) $p=0.03$
Pleasantness	-0.05 (0.02) $p=0.002$	0.02 (0.02) $p=0.34$
Boredom	0.01 (0.02) $p<0.001$	0.02 (0.02) $p=0.40$
Sweetness	-0.04 (0.02) $p=0.05$	0.005 (0.02) $p=0.80$

* Significantly different from zero (T-test $p<0.05$)

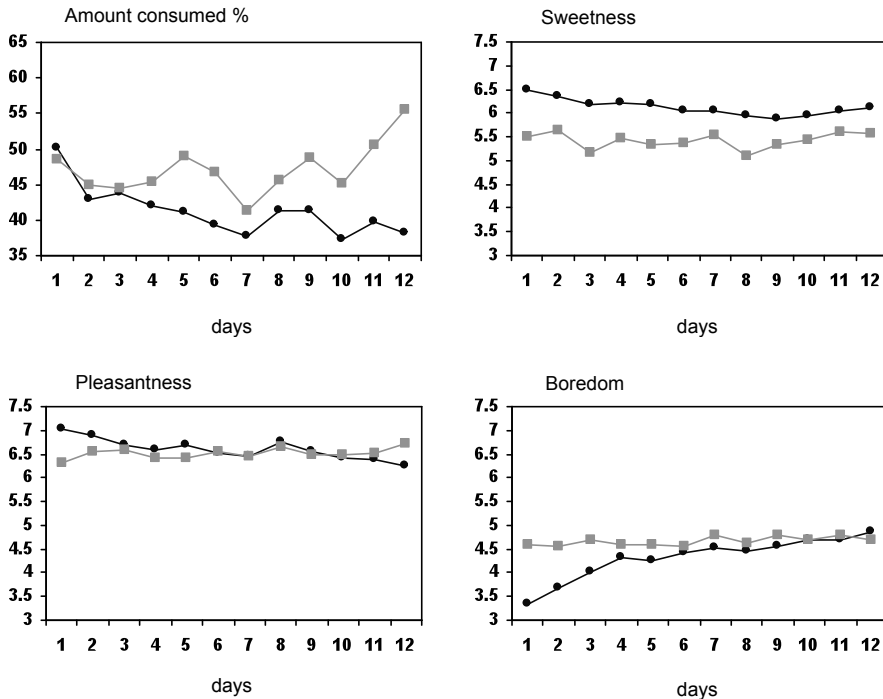


Figure 1. Mean ratings for amount consumed, pleasantness, boredom, amount of thirst and sweetness for the 3 fruit drinks together during 12 days for the young (n=32) -●- and the elderly -■- (n=36) participants.

Changes after 12 days in the amount consumed and sensory/motivational ratings for the three orange-based drinks separately per age group

Table 5 describes the mean slopes of the consumption, pleasantness, boredom and sweetness for each drink per age group. Within the young group, the orange peach drink showed the most changes. The consumption of only this drink decreased from 0.54 L on day 1 to 0.36 L on day 12 ($p=0.01$) whereas consumption for the elderly group did not change ($p=0.17$). When the mean slopes were compared, ANOVA showed no difference in change in consumption over 12 days between the three fruit drinks for the young $F(2,92)=0.45$, $p=0.64$ and for the elderly $F(2,105)=0.05$, $p=0.95$.

In the young group, the pleasantness ratings for the orange peach drink and for the orange juice both declined from 7.4 to 6.2 ($p=0.007$) and from 8.1 to 7.4 ($p=0.001$), respectively. The ratings for both drinks did not change in the elderly group ($p=0.77$ and $p=0.99$). The mean slopes did not differ among the three drinks for the young

$F(2,90)=0.92$, $p=0.40$ or for the elderly $F(2,103)=0.76$, $p=0.47$.

The boredom ratings in the young group increased for all the drinks. The orange peach drink increased from 3.3 to 5.3 ($p<0.001$), the orange juice from 2.5 to 3.5 ($p=0.001$) and the orange mandarin increased from 4.3 to 5.8 ($p=0.001$). However, the boredom ratings for the drinks did not increase in the elderly group. The mean slopes did not differ among the three drinks for the young $F(2,90)=0.29$, $p=0.75$ and for the elderly $F(2,100)=1.01$, $p=0.37$.

The sweetness ratings for the orange peach drink only increased in the young ($p=0.006$) but not in the elderly group ($p=0.24$). There was no difference between the change in sweetness of the three drinks over 12 days within the young $F(2,88)=0.68$, $p=0.51$ and the elderly group $F(2,102)=0.73$, $p=0.48$.

Table 5. Mean slopes (SD) and p values representing the change per day in amount consumed, pleasantness, boredom and sweetness for each fruit drink during 12 days for the young and the elderly women

Variable	Orange mandarin		Orange juice		Orange peach	
	Young	Elderly	Young	Elderly	Young	Elderly
Amount consumed %	-0.52 (0.39) $p=0.18$	0.54 (0.36) $p=0.13$	-0.72 (0.44) $p=0.10$	0.36 (0.40) $p=0.36$	-1.05 (0.41) $p=0.01^*$	0.53 (0.38) $p=0.17$
Pleasantness	-0.02 (0.03) $p=0.52$	0.05 (0.03) $p=0.12$	-0.06 (0.02) $p=0.001^*$	0.00 (0.03) $p=0.99$	-0.07 (0.03) $p=0.007^*$	-0.008 (0.03) $p=0.77$
Boredom	0.13 (0.03) $p<0.001^*$	-0.02 (0.04) $p=0.66$	0.09 (0.03) $p=0.001^*$	0.06 (0.03) $p=0.08$	0.12 (0.03) $p<0.001^*$	0.01 (0.04) $p=0.74$
Sweetness	-0.03 (0.03) $p=0.39$	-0.005 (0.03) $p=0.87$	-0.03 (0.03) $p=0.39$	0.04 (0.03) $p=0.23$	-0.06 (0.02) $p=0.006^*$	-0.03 (0.03) $p=0.24$

*Significantly different from zero (T-test $p<0.05$)

DISCUSSION

This study shows that in a real life setting, elderly women did not experience increased boredom and expressed stable pleasantness ratings after a repeated monotonous exposure to three orange-based drinks. In contrast, the consumption and pleasantness ratings for the young women decreased while their boredom ratings increased. The orange peach drink which was rated as the sweetest and most pleasant drink, contributed the most to the effect of the repeated monotonous exposure in young people.

Based on a study by Pelchat and Schaefer (2000) it was anticipated that the elderly would probably not develop boredom and a lower acceptance to the drinks as a result of repeated exposure while the young participants most likely would. Our results are in line with their finding that elderly are unresponsive to a monotonous treatment.

The results of this study were obtained by using fruit drinks varying in sweetness intensity. It is possible that the use of products from other food categories could change our outcome. The effect of the monotonous repeated exposure may be influenced by several aspects including initial pleasantness ratings, the intensity of various sensory attributes, regular frequency of consumption, whether foods are considered to be novel or staple, duration and amount of exposures and interval of exposures (Schutz and Pilgrim 1958, Hetherington et al 2000). The pleasantness ratings of staple foods such as bread, butter and milk do not change after repeated consumption (Siegal and Pilgrim 1958, Schutz and Pilgrim 1958).

The various sweetness intensities of the fruit drinks differ in the extent to which they contributed to the effect of the monotonous repeated exposure. The orange mandarin drink contributed the least to the effect. This indicates that the drink with the lowest sweetness intensity is most liked on the long term. A similar finding was reported by Vickers and Holten (1998) who showed that stronger tea led to a stronger decline in pleasantness after repeated exposure than weaker tea. Monneuse et al (1991) also found that low intensity tastes were more appreciated when repeated stimulation occurred.

Our finding differs from the proposal by Schutz and Pilgrim (1958) that foods with initially high pleasantness rates do not develop a lowered acceptance during a monotonous repeated exposure and become even more liked. We found that the orange peach drink which had the highest sweetness and pleasantness ratings, added the most to the effect of the repeated exposure. A similar result was also found with chocolate which was rated as most pleasant compared to French fries but whose pleasantness ratings and preference decreased after repeated exposure (Hetherington et al 2000). It seems that people may tire more easily of foods that are highly liked and are not regularly consumed on a daily basis (Moskowitz 1980).

Our results were observed in a female population since only women responded to our invitation. We believe it is unlikely that these results would not apply to a male population since in another study, both men and women showed the same reaction

Chapter 2

to a monotonous exposure (Pelchat and Schaefer 2000). Also, the diminished sensory-specific satiety seen in elderly seems not to be gender-related (Rolls and McDermott 1991).

Most studies on the effects of repeated monotonous exposure on boredom have taken place in a laboratory setting instead of a real life situation (Pelchat and Schaefer 2000, Hetherington et al 2002 & 2000). To eliminate the biasing effect of the laboratory environment on attributes (Meiselman et al 2000) and thus to obtain more realistic ratings for pleasantness and intake our participants performed the test in their homes. The results of our study are comparable to the results of other studies which have been performed in a laboratory setting (Pelchat and Schaefer 2000, Hetherington et al 2000 & 2002).

Similar to our finding within the elderly group, Koskinen et al (2003) also found stable boredom ratings for elderly participants. In their in home study, young and elderly participants received snack products different in aroma concentration for 6 days. They found a decrease in ratings on willingness to eat the products again with increased aroma concentration for the young group but not for the elderly people. It could be that intake and boredom ratings were not affected because the duration of exposure (6 days) might not have been long enough to actually trigger intake and boredom ratings. The 12-day findings of the young women in our study correspond with the long-term effects found by Zandstra et al (2000). Results from their in home test showed a significant increase in boredom and a decline in acceptance ratings and consumption after repeated consumption of the same flavor of meat sauce once a week for a period of 10 weeks.

The pleasantness ratings at baseline and the overall sweetness ratings for the three drinks were lower for the elderly than for the young people. The lower sweetness ratings are probably because elderly people are most likely less sensitive to higher sucrose concentrations. In a study by Philipsen et al (1995) elderly were less sensitive to changes in flavor concentration because their hedonic responses did not change with increasing aroma concentration. They are also less sensitive to sensory-specific satiety (Rolls and McDermott 1991) so most likely, elderly people tire less of a certain taste. This could contribute to why their boredom ratings remained constant and intake did not decrease upon repeated consumption.

Since elderly women did not experience an increased boredom over time, chances are they might not be internally stimulated enough to switch to other products. As a consequence their dietary variety may be limited which may lead to inadequate

nutrient intake and therefore contribute to dietary inadequacies (Roberts 2000 and Bernstein et al 2002). An increase in dietary variety is associated with increased energy intake in healthy adults (McCrary et al 1999) and a better nutritional status among frail nursing home elderly (Bernstein et al 2002). Therefore, future research should focus on appetite-stimulating features of meals and foods for elderly people to stimulate a diet high in variety.

In conclusion, no increased boredom was experienced by elderly women in a real life situation after ad libitum intake of three orange-based fruit drinks for 12 days. However, boredom did increase in the young women. The sweetest and the most pleasant rated drink contributed the most to the effect of the repeated monotonous exposure in the young women.

REFERENCES

- Bernstein MA, Tucker KL, Ryan ND, O'Neill EF, Clements KM, Nelson ME, et al Higher dietary variety is associated with better nutritional status in frail elderly people. *J Am Diet Assoc* 2002;102:1096–1104
- Brown EL. Factors influencing food choices and intake. *Geriatrics* 1976;31:89–92
- De Graaf C, Polet P, van Staveren WA. Sensory perception and pleasantness of food flavors in elderly subjects. *J Gerontol* 1994;49:93–99
- De Graaf C, van Staveren W, Burema J. Psychophysical and psychohedonic functions of four common food flavours in elderly subjects. *Chem Senses* 1996;21:293–302
- De Jong N, De Graaf C, Van Staveren WA. Effect of sucrose in breakfast items on pleasantness and food intake in the elderly. *Physiol Behav* 1996;60:1453–1462
- Fanelli MT, Stevenhagen KJ. Characterizing consumption patterns by food frequency methods: core foods and variety of foods in diets of older Americans. *J Am Diet Assoc* 1985;85:1570–1576
- Hetherington MM, Bell A, Rolls BJ. Effects of repeat consumption on pleasantness, preference and intake. *Br Food J* 2000;7:507–521
- Hetherington MM, Pirie LM, Nabb S. Stimulus satiation: effects of repeated exposure to foods on pleasantness and intake. *Appetite* 2002;38:19–28
- Hetherington MM, Rolls BJ, Burley VJ. The time course of sensory- specific satiety. *Appetite* 1989;12:57–68
- Koskinen S, Kalviainen N, Tuorila H. Flavor enhancement as a tool for increasing pleasantness and intake of a snack product among the elderly. *Appetite* 2003;41:87–96
- McCrary MA, Fuss PJ, McCallum JE, Yao M, Vinken AG, Hays NP, et al Dietary variety within food groups: association with energy intake and body fatness in men and women. *Am J Clin Nutr* 1999;69:440–447
- Meiselman HJ, Johnson JL, Reeve W, Crouch JE. Demonstrations of the influence of the eating environment on food acceptance. *Appetite* 2000;5:231–237
- Monneuse MO, Bellisle F, Louis-Sylvestre J. Responses to an intense sweetener in humans: immediate preference and delayed effects on intake. *Physiol Behav* 1991;49:325–330
- Morley JE. Anorexia of aging: physiologic and pathologic. *Am J Clin Nutr* 1997;66:760–773
- Moskowitz HR. Psychometric evaluation of food preferences. *J Foodserv Syst* 1980;1:149–167
- Murphy C, Withee J. Age and biochemical status predict preference for casein hydrolysate. *J Gerontol* 1987;42:73–77
- Murphy C, Withee J. Age-related differences in the pleasantness of chemosensory stimuli. *Psychol Aging* 1986;1:312–318
- Murphy C. Nutrition and chemosensory perception in the elderly. *Crit Rev Food Sci Nutr* 1993;33:3–15
- Pelchat ML, Schaefer S. Dietary monotony and food cravings in young and elderly adults. *Physiol Behav* 2000;68:353–359

- Philipsen DH, Clydesdale FM, Griffin RW, Stern P. Consumer age affects response to sensory characteristics of a cherry flavoured beverage. *J Food Sci* 1995;60:364–368
- Pliner P. The effect of mere exposure on liking for edible substances. *Appetite* 1982;3:283–290
- Roberts SB. Energy regulation and aging: recent findings and their implications. *Nutr Rev* 2000;58:91–97
- Rolls BJ, McDermott TM. Effects of age on sensory-specific satiety. *Am J Clin Nutr* 1991;54:988–996
- Rolls BJ. Appetite, hunger, and satiety in the elderly. *Crit Rev Food Sci Nutr* 1993;33:39–44
- Rolls BJ. Do chemosensory changes influence food intake in the elderly? *Physiol Behav* 1999;66:193–197
- Rolls ET, Rolls BJ, Rowe EA. Sensory-specific and motivation-specific satiety for the sight and taste of food and water in man. *Physiol Behav* 1983;30:185–192
- Schiffman SS. Perception of taste and smell in elderly persons. *Crit Rev Food Sci Nutr* 1993;33:17–26
- Schutz HG, Pilgrim FJ. A field study of food monotony. *Psychol Rep* 1958;4:559–565
- Ship JA, Weiffenbach JM. Age, gender, medical treatment, and medication effects on smell identification. *J Gerontol Med Sci* 1993;48:M26–32
- Siegal PS, Pilgrim FJ. The effect of monotony on the acceptance of food. *Am J Psychol* 1958;71:756–759
- Stevens JC, Bartoshuk LM, Cain WS. Chemical senses and aging: taste versus smell. *Chem Senses* 1984;9:167–179
- Vickers Z, Holten E. A comparison of taste test rating, repeated consumption, and postconsumption ratings of different strengths of iced tea. *J Sens Stud* 1998;13:199–212
- Zallen EM, Hooks LB, O'Brien K. Salt taste preferences and perceptions of elderly and young adults. *J Am Diet Assoc* 1990;90:947–950
- Zandstra EH, de Graaf C, van Trijp HCM, van Staveren WA. Laboratory hedonic ratings as predictors of consumption. *Food Qual Prefer* 1999;10:411–418
- Zandstra EH, De Graaf C, Van Trijp HCM. Effects of variety and repeated in home consumption on product acceptance. *Appetite* 2000;35:113–119

3

No effect on intake and liking of soup enhanced with MSG and celery powder among elderly people with olfactory and/or gustatory loss

Natasja H Essed • Suzanne Kleikers • Wija A van Staveren • Frans J Kok •
Cees de Graaf • *Int J Food Sci Nutr* 2009;22:1-12

ABSTRACT

MSG and/or flavors may improve palatability and intake in elderly people. Whether this improvement is related to a decline in chemosensory sensitivity is unclear. We examined the effect of flavor-enhanced tomato soup (1200 mg/L MSG (0.12% MSG) + 3g/L celery powder) versus non-enhanced soup on intake and liking in 120 older adults (72±6 years). Olfactory and gustatory performance was measured. For the whole group, no difference in intake (198 g vs. 203 g) ($p=0.97$), liking (6.6 vs 6.7) ($p=0.99$) and strength (7.2 vs 7.2) ($p=0.76$) between the soups was found. Intake ($p=0.52$), liking ($p=0.90$) and strength ($p=1.00$) between the soups were not different within the low olfactory/low gustatory group. Intake and liking of the flavor-enhanced soup was not increased within elderly with low chemosensory sensitivity. Enhancing flavors to increase intake and liking may not be a uniform approach due to the heterogeneity in chemosensory losses among elderly people.

INTRODUCTION

With increasing age there is a decline in food and energy intake (Morley 1997, 2001) in groups of both healthy noninstitutionalized (Wurtman et al 1988) and institutionalized elderly people (Lowik et al 1992, van der Wielen et al 1995). Another associated issue with aging is the reduction in body weight (Lehmann and Bassey 1996) which even in the case of a small decrease is an important and independent marker of risk of mortality in elderly (Newman et al 2001). An insufficient dietary intake and weight loss may predispose to the development of malnutrition in the elderly (Mowé et al 1994, Chen et al 2001)

Changes in the hedonic qualities of food with aging appear to be due to the decrease in taste sensitivity (Stevens et al 1995) and in smell identification (Doty et al 1984). Data from this last study showed that more than 60 percent of people aged between 65-80 years and tested for smell identification ability had major olfactory impairment. This percentage raised to more than 80 in people tested over the age of 80 years with nearly 50 percent being anosmic (no sensation of smell). The older adults also seem to have higher olfactory detection and recognition thresholds and a loss of suprathreshold odor intensity perception according to the magnitude estimation method (Schiffman 1993). Out of the two senses, smell is more affected than taste and the olfactory decline typically begins around 60 y of age and becomes more severe in people older than 70 year of age (Stevens et al 1984, Doty et al 1984, Murphy et al 2002, Morley 1997).

Generally older adults prefer higher optimal flavor concentrations (by boosting a taste or certain aromas) in a certain number of foods than young people (de Graaf et al 1994, de Graaf et al 1996, Griep et al 2000, de Jong et al 1996, Kozłowska et al 2003, Murphy and Withee, 1987). This finding is possibly related to the results found in other studies that enhancing food with flavors and or MSG can increase palatability (Schiffman and Warwick 1993, Schiffman 1998, Schiffman and Warwick 1988) and intake in elderly (Mathey et al 2001) and in older adults suffering from malnutrition (Schiffman 1998). The results of these studies may concur with the theory that the alterations in taste and smell performance are associated with an increased liking of flavor-enhanced foods versus non-enhanced foods. However, it has been difficult to relate higher optimal flavor concentration to lower performances in sensory tests (Koskinen et al 2003b, Forde and Delahunty 2004, Kremer et al 2007c, Koskinen and Tuorila 2005). Besides, not all studies find positive effects of flavor enhancement on intake and liking in elderly people (Mojet et al 2005, Koskinen et al 2003b).

So far little is known about intake and liking of flavor-enhanced foods among older adults with a decline in taste and/or smell performance. Therefore, this study examined the effect of tomato soup enhanced with mono sodium glutamate (MSG) and celery powder against non-enhanced soup on liking and intake among older people with a diminished taste and/or smell performance.

PARTICIPANTS AND METHODS

This study was conducted at Wageningen University, The Netherlands in 2002. The participants were recruited in clubs for the elderly in Wageningen and surrounding villages, through phone calls and from a database from Wageningen Centre of Food Sciences. The participants were told that during a 6 week study they had to rate the liking of tomato soup of which the flavor was enhanced.

All participants were screened using i) a general questionnaire including questions about the age of the participants, whether they lived independently, their medication use, if they suffered from diseases or had trouble breathing through their nose, about denture use, alcohol use, smoking behavior, meal preparation and their sensitivity to MSG, celery and tomato and ii) the Dutch Eating Behavior questionnaire (Van Strien et al 1986) consisting of 33 items containing three scales for the measurement of the degree of: emotional eating (13 items), externally induced eating (10 items) and restrained eating (10 items). For this study, we measured the attempts to refrain from eating and participants were only included if their restrained score was <3.2.

The inclusion criteria were: aged 60 and older, living independently, capable of preparing his/her own food, no known dementia or depression and use of antidepressants, no disease in terminal phase, non restrained eaters and no disorder to tomato soup, celery or MSG. After screening, 126 participants (40 men and 86 women) were included in the study and provided their written informed consent. The protocol of the study and all the material provided to the participants was approved by the Medical Ethical Review Committee of the Division of Human Nutrition of Wageningen University.

Design

This study consisted of a single blind within subjects cross over design. All the participants came to the laboratory of the university on 6 test days. They started with a test to measure olfactory sensitivity on the first day and a gustatory test on the second day. On the other 4 test days, participants consumed either the flavor-enhanced tomato soup or the non-enhanced (regular) tomato soup. Both soups were consumed twice. The order of consumption of the four soups was randomly assigned to each subject.

Stimuli

The soup in this study (Unox Soup-It, tomato) was provided by Unilever Bestfoods, Heilbronn, Germany. On each test day, the soup was poured out into 2 pans and processed with a hand blender (Braun, MR430HC) to a smooth consistency during 1 minute. The flavor-enhanced soup (soup B) was prepared by adding 1200 mg MSG (Ve Tsin, Silvo, The Netherlands)/L plus 3 g celery powder/L to the regular soup (soup A).

The amount of 1200 mg MSG/L soup was based on a previous study by Mathey et al (2001). Celery powder is used as a flavor because of its volatile components (60-70% limonene, 5-10% selinene, 15% phtalides (sedanenolide, 3- n-butylphthalide, and sedanolide)) and it goes well with tomato soup. The dosage of the celery powder was determined in a pre-tasting session in which five concentrations were tested (0.5 g/L, 1 g/L, 1.5 g/L, 2 g/L and 3 g/L) in ready to eat tomato soup (Unox soup-it). It was decided that 3 g celery powder/L was appropriate to enhance the tomato soup with since at that level a difference in flavor was perceived between the enhanced soup and non-enhanced soup.

Measurements

Olfactory capability

The European test of Olfactory Capabilities (ETOC) (Neurosciences et Systemes Sensoriels, Universite Claude Bernard Lyon 1, France and HealthSense) is based on sixteen blocks of four vials of which only one vial (15 mL) contains an odor (Thomas-Danguin et al 2003). The odors are: vanilla, cloves, apple, eucalyptus, cinnamon, fuel-oil, pine, garlic, cut grass, anise, orange, fish, rose, thyme, lemon and mint. To evaluate the olfactory performance, a detection task was given followed by an identification task by selecting the right descriptor among the four options.

The ETOC score (maximum score = 32) is the sum of the correct detection score and the correct identification score. A correct identification answer was only included when the correct accompanying detection answer was given.

Cutoff values for normal performance resulting from 95% confidence limits for different age groups were established upon 1330 European participants with the ETOC (Rouby, personal communication). The correct answers from our participants were compared to these cutoff values according to age. Normal olfactory performance for 50-59 year: if detection score is ≥ 15 and identification score is ≥ 13 ; for 60-69, if the scores are ≥ 15 and ≥ 12 and for age 70-79 if the scores are ≥ 14 and ≥ 11 . For ≥ 80 year, normal olfactory performance: if detection score is ≥ 13 and identification score is ≥ 9 .

Gustatory test

The gustatory test was used to determine gustatory capabilities for common tastants in elderly people (Swedish Institute for Food and Biotechnology, Gothenburg) (Johansson et al 2004). The test consisted of 16 samples which were 4 concentrations of each of the stimuli dissolved in water: sucrose (sweet) (0.0032 M, 0.01 M, 0.032 M, 0.1 M), sodium chloride (salt) (0.0032 M, 0.01 M, 0.032 M, 0.1 M), citric acid (sour) (0.00063 M, 0.0013 M, 0.0025 M, 0.0050 M) and quinine hydrochloride (bitter) (0.0000038 M, 0.0000083 M, 0.000018 M, 0.000040 M). The samples were served at room temperature in 10 mL portions in 50 mL disposable plastic cups, labeled 1-16. The participants were instructed to start with sample 1 through to sample 16 and to rinse their mouth with water and wait for 45 seconds before proceeding to the next sample. They had to identify the taste by taking the whole sample in their mouth, taste it and then to spit it out. Next, the participants had to mark their perceived intensity on a labeled magnitude scale of 150 mm. The anchor words (% of the full scale) were: none (0%), barely detectable (2%), weak (6%), moderate (17%), strong (35%), very strong (53%) and strongest imaginable (100%).

For the gustatory test a total gustatory capability score (maximum score=40) for each participant was calculated by combining identification and intensity information. This score consists of the total number of correct identifications for all four tastes (maximum score= 16) and the total number of correct intensity ranking score for all the tastes (maximum score=24). The intensity ranking score was correct if in a pair-wise comparison the perceived intensity of a certain sample of a stimulus (sweet, sour etc) was judged to be higher than the perceived intensity of a sample with a lower concentration of the same stimulus. If the perceived intensity was judged lower

than or equal to the perceived intensity of a sample of the same stimulus with a lower concentration, then the rank order was considered to be wrong. For each stimulus there are six possible intensity comparisons which give a maximum score of 24 if the correct intensity scores of all stimuli were added up.

The mean of the total gustatory capability score (27.2) was used as a cutoff value (the mean is taken because the scores were normally distributed). Participants with a total gustatory capability score of ≥ 28 were considered to have normal gustatory capability.

Soup intake

All the participants were instructed verbally as well as in writing not to smoke, drink (with the exception of water), brush their teeth or eat food less than an hour before each test. The participants came to laboratory at 11.30 in the morning on the same day during 4 weeks. They sat in groups of four at a table and each group was different during each session. Before the soup was served, they answered two questions about their health; if they had a cold and if they felt fit that day (both yes/no). Each person was then randomly served approximately 500 g of one of the soups that was prepared according to the instructions on the package and served at 75 °C in a labeled cup with a plastic spoon. The participants were not aware which soup (A or B) it concerned so not everyone in the group received the same soup. Before eating, participants rated their desire to consume tomato soup at that time. Liking and strength of the taste of the soup were rated while eating. All attributes were rated on a 10-point scale. The left anchors (=1) were explained as no desire to eat at all, not pleasant at all, not strong at all and the right anchors (=10) were extreme desire to eat, extremely pleasant, and extremely strong. We encouraged the participants to eat as much soup as they pleased and the meal ended after the consumption of the soup. During the meal which lasted about 30 minutes, the participants were asked not to talk about their attribute ratings and this was checked by the researchers by being present in the laboratory. The cup containing the soup was weighed before serving and intake was measured by weighing the returned cups with the remaining soup.

Statistics

To determine if the added MSG and celery powder to soup would lead to an increase in intake and liking among elderly people with a certain condition of olfactory and gustatory loss, participants were divided into four groups when the olfactory and the gustatory cutoff values were combined. Group 1 had normal olfactory and normal

gustatory, group 2 had normal olfactory and low gustatory, group 3 had low olfactory and normal gustatory and group 4 had low olfactory and low gustatory scores.

Differences in general characteristics (weight, BMI, restrained score, olfactory scores) between the four groups were determined using Kruskal-Wallis test. For age and total gustatory capability score one-way analysis of variance was used. Differences in gender distribution and smoking behavior between the four groups were tested using the Chi-Square test.

The difference in intake, desire, liking and strength between the plain soup (A) and flavor-enhanced soup (B) within a group were assessed using the Wilcoxon Signed Rank Test. The Kruskal-Wallis test was used to compare these differences (delta's) between the four groups.

All statistical analyses were performed with SPSS for WINDOWS software (version 11.5; SPSS Benelux, Gorinchem, The Netherlands). A p value <0.05 was considered significant.

RESULTS

The results of 120 participants (38 men and 82 women) were analysed and no major health problems were reported on the test days. Data of 6 participants were not included because of antidepressant use (3) and a restrained score >3.2 (3). There was a difference between the four groups in olfactory detection score, olfactory identification score and total gustatory capability score ($p < 0.001$) (Table 1). On the other hand, no significant difference was found between the four groups in age, gender, body weight, BMI, except for smoking behaviour. For the total population, the mean score for olfactory detection was 13.4 (± 3.3) and for identification 9.7 (± 3.6). Out of 16 odours, on average 13 were correctly detected and 10 were correctly identified. For the gustatory test, the mean total gustatory score for the older adults was 27.2 (± 4) and the scores ranged from 16-35.

Table 1. Mean general characteristics (and SD) of independently living older adults divided into four groups of olfactory and gustatory performance

Characteristics	Total population (n=120)	Normal olfactory + normal gustatory (n=25)	Normal olfactory + low gustatory (n=23)	Low olfactory + normal gustatory (n=34)	Low olfactory + low gustatory (n=38)
Age (y)	72 (6)	73 (6)	70 (7)	73 (6)	72 (5)
Men/Women	38 / 82	6 / 19	4 / 19	11 / 23	17 / 21
Body weight (kg)	74.1 (11.6)	70.6 (9.4)	71.9 (7.4)	77.1 (14.5)	75.1 (11.9)
BMI (kg/m ²)	26.3 (4.4)	25.9 (3.2)	25.9 (4)	26.9 (5.8)	26.4 (4)
Restrained score ^a	2.2 (0.6)	2.4 (0.6)	2.2 (0.7)	2.3 (0.6)	2.1 (0.6)
Smoking (y/n)%	7 / 93	4 / 96	17 / 83	9 / 91	3 / 97
Olfactory scores ^b	13.4 (3.3)	15.4 (0.8)	15.2 (0.7)	12.2 (3.3)	12.3 (4.1)
-Detection	9.7 (3.6)	12.5 (1.3)	12.7 (1.4)	7.6 (3.3)	7.9 (3.5)
-Identification					
Total Gustatory capability score ^c	27.2 (4)	30.6 (1.9)	24.8 (1.8)	30.6 (1.8)	23.5 (3.2)

^a The restrained score was measured with the Dutch Eating Behaviour Questionnaire (Van Strien et al 1986)

^b The detection and identification score are the amount of right answers for the detection task and the identification respectively, of the European Test of Olfactory Capabilities (ETOC) (Thomas-Danguin et al 2003)

^c The total gustatory capability score is the sum of the amount of right answers for the identification task and the amount of right intensity rankings of the gustatory test developed by the Swedish Institute for Food and Biotechnology, Gothenburg (Johansson et al 2004)

Soup intake, desire, liking and strength

No significant difference was found in intake ($p=0.97$), desire ($p=0.57$), liking ($p=0.99$) and strength ($p=0.76$) between the plain (A) and the flavor-enhanced soup (B) for the total population ($n=120$) (Table 2). For each of the four groups, there was no difference in intake ($p\geq 0.52$), desire ($p\geq 0.26$), liking ($p\geq 0.60$) and strength ($p\geq 0.35$). Also, no difference was found when the changes in intake ($p=0.92$), desire ($p=0.56$), liking ($p=0.9$) and strength ($p=0.79$) were compared between the soups.

Table 2. Mean values (SD) and changes of intake (g), liking, desire and taste strength of plain (A) and enhanced (B) tomato soup of independently living older adults divided into four groups of olfactory and gustatory performance. Anchors for liking, desire and strength: 1= not at all; 10= extreme)

Variable	Normal olfactory + normal gustatory (n=25)			Normal olfactory + low gustatory (n=23)			Low olfactory + normal gustatory (n=34)			Low olfactory + low gustatory (n=38)		
	A	B	Δ	A	B	Δ	A	B	Δ	A	B	Δ
Intake	223 (156)	207 (126)	16 (84)	192 (117)	194 (118)	2 (82)	217 (115)	209 (110)	8 (85)	184 (112)	185 (114)	2 (74)
Liking	7 (1.1)	7 (1.3)	0 (1.2)	6.7 (1.4)	6.5 (1.3)	0.2 (1.9)	6.5 (1.5)	6.5 (1.2)	0 (1.7)	6.5 (1.7)	6.5 (1.4)	0 (1.2)
Desire	6.5 (1.9)	6.2 (1.8)	0.3 (1.3)	6.3 (1.5)	6.0 (1.5)	0.3 (1.1)	6.1 (1.9)	6.3 (1.8)	0.2 (1.1)	6.2 (1.9)	6.2 (1.7)	0 (1.6)
Strength	7.3 (0.8)	7.4 (0.9)	0.1 (0.9)	7.4 (0.9)	7.1 (1.3)	0.3 (1.5)	7.2 (0.9)	7.2 (1.2)	0 (1.2)	7.1 (1.1)	7.1 (0.9)	0 (1.1)

Δ indicates the absolute change

Psychometric properties of the performance tests

The reliability analysis for the gustatory test showed that the internal consistency (Cronbach's alpha) between the scores for salt, sweet, sour and bitter was 0.39. We found correlations between the scores for salt, sweet, sour and bitter (salt-sweet, $r=0.23$; salt-sour, $r=0.22$; salt-bitter, $r=0.05$; sweet-sour, $r=0.30$; sweet-bitter, $r=0.03$, sour-bitter, $r=0.17$). For the olfactory test we found an alpha of 0.86 with correlations between the odors varying from 0.01(thyme-vanilla) to 0.59 (anise-eucalyptus).

The calculated correlation between the olfactory test and the gustatory test scores (Figure 1) was not significant ($N=120$, $r=0.134$, $p=0.144$) meaning that the olfactory performance is not related to gustatory functioning in this study.

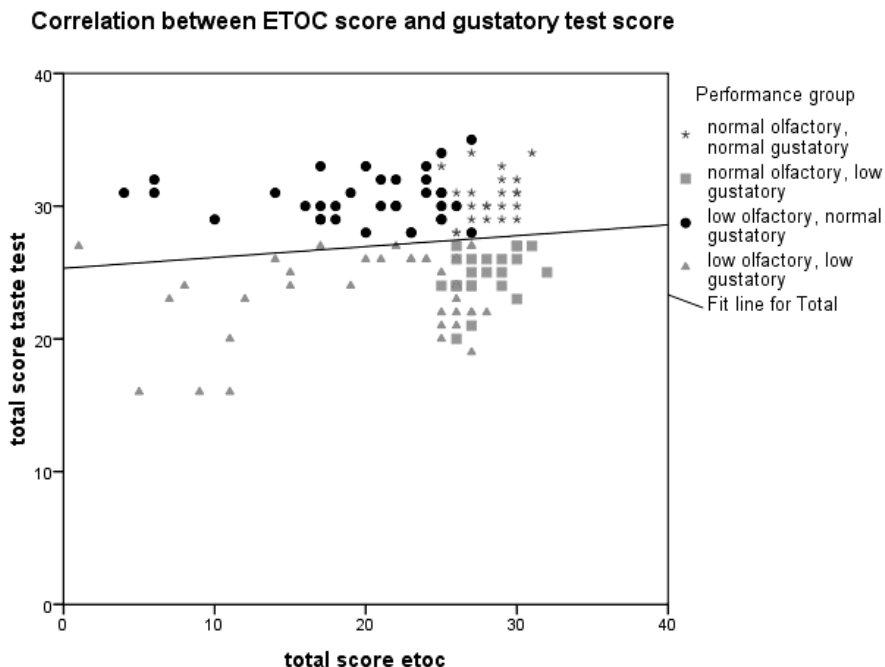


Figure 1. Correlation between the olfactory capability score and the gustatory capability score

DISCUSSION

This study attempted to assess whether there is an effect of tomato soup enhanced with mono sodium glutamate (MSG) and celery powder against non-enhanced soup on liking and intake among older people with a diminished taste and/or smell performance. Previous research has suggested that older adults may have a higher preferred optimal concentration level for certain flavors or a taste compared to young people (de Graa et al 1994, de Graaf et al 1996, Griep et al 2000, de Jong et al 1996, Kozłowska et al 2003, Murphy and Withee 1987). We therefore expected that the elderly people with a diminished taste and smell performance would show an increased liking and/or intake of tomato soup enhanced with MSG and celery powder compared to non-enhanced soup. However, no increase was found for liking, intake and taste strength within the group with both low olfactory and low gustatory performance or in any of the other groups.

During a pre-tasting session, healthy and young participants were able to distinguish the enhanced from the non-enhanced soup. Based on this we expected that the

enhanced soup would be appropriate for the elderly but we do not know this for certain. Having a range of MSG concentrations and celery powder tested in the groups of elderly instead of young adults to determine at which concentration a difference between the soups can be perceived would have given us a decisive answer. No difference was perceived for liking and strength between the two soups in within any of the four performance groups. Reviewing individual data showed no strong evidence that the difference was perceptible among the elderly. This may indicate that possibly our dosage was too low for the elderly.

Our results are in contradiction with the outcome of Bellisle et al (1991, 1996) who found an increased intake of some foods with 0.6% MSG among elderly people. Schiffman (1998) found that 0.3% -1.0% MSG improved acceptability in a number of foods among malnourished elderly people and Prescott and Young (2002) improved liking of vegetable soup using 0.8% MSG among participants aged 20-68 yrs. On the other hand, there are studies that find similar results to ours. Among elderly people Mojet et al (2005) found no difference between liking ratings of samples with MSG concentrations ranging from 0.16% to 1% in broth. In a recent study by Essed et al (2007) involving institutionalized elderly, no effect on liking and intake was found upon consumption of a hot meal enhanced with 700 mg flavors and/or 300 mg MSG during 16 weeks.

The differences in outcome of the above studies suggest that flavor enhancement of foods as a way to increase liking and/or intake may not be a 'one size fits all' approach. This suggestion is further strengthened by other studies that found no correlation between chemosensory functioning and an increased intake and/or liking of flavor-enhanced foods (Kremer et al 2007a, Griep et al 2000). For instance, Koskinen et al (2003b) showed that despite impaired olfactory capabilities, liking ratings and intake of elderly participants (63-85 yrs) did not increase upon consumption of a yoghurt-like product with extra red currant aroma. In line with Koskinen et al, but focused on taste perception Mojet et al (2005) showed that the optimal preferred concentration of different levels of NaCl/KCl; acetic acid/citric acid; caffeine/quinine and MSG/IMP in foods were not different between the young and the elderly when tasted. Accordingly, no association was found between a preference for enhanced foods and an age related loss of taste sensitivity.

The difficulty of increasing liking and/or food intake by means of flavor enhancement is that the chemosensory losses may be taste and/or flavor specific and the degree of the taste and/or smell loss may vary between individuals. Recent studies have shown that elderly people are a heterogeneous group when it comes to olfactory functioning

because the olfactory performance of some older adults show overlap with the young adults (Thomas-Danguin et al 2003, Koskinen et al 2003a, Forde and Delahunty 2004). Also, the use of certain medication (Smith and Bidlack 1984) and denture wear (Boucher et al 2006, Sayoun and Krall 2003, Griep et al 1997, Kapur and Soman 1964, Wayler et al 1990) which both could interfere with intake and liking are not the same for the entire older adult population.

Both the olfactory (ETOC) and gustatory test used in this study are relatively new. They were developed for the Health Sense project (<http://healthsense.ucc.ie>) and the quality of these two tests will be briefly discussed. For the gustatory test a low correlation was found between the four items (salt, sweet, sour and bitter). It appears that the total gustatory score is not fully explained by the total scores for each salt, sweet, sour and bitter and is more complex than the sum of these scores. This is probably because the items each evaluate a different type of taste. We are aware of the discussion regarding the recognition of umami as the fifth basic taste, perhaps its absence as an item in the gustatory test matters for the outcome of the internal consistency. The sensitivity for umami as a taste was not measured with the gustatory test among our elderly participants. Since Mojet et al (2001) found no difference between the mean threshold for MSG of healthy, non institutionalized elderly men and women (60-75 yrs) and the mean threshold of their younger counterparts; this suggests that their perception for MSG was intact. Whether this finding can be extrapolated to our population is not certain since they took prescribed medication which was not the case in the study by Mojet et al For the ETOC test, the reliability analysis revealed an alpha coefficient that was closer to 1 meaning that the sixteen items (odors) making up the total score are better correlated. This implicates that the sixteen odors measure the same construct, in this case the ETOC score.

In conclusion, this study showed no relationship between an increased liking or intake of flavor-enhanced foods and a decline in chemosensory performance. Given the fact that the elderly are a heterogeneous group it is important for future research to focus more on the individual older adult and their status of chemosensory functioning to gain insight if the decrease of sensory perception is sufficient to require a compensation strategy. In light of this the development and use of more advanced and better sensory tests are needed for measuring the sensory impairment to come up with a more fitted approach to treat the effect of age on the senses, depending on the kind and the degree of sensory loss. To improve the dietary intake and sensory experience, other approaches such as altering the eating environment by improving the ambiance also deserve more attention, as they are significant determinants of food intake.

REFERENCES

- Bellisle F, Dalix AM, Chappuis AS, Rossi F, Fiquet P, Gaudin V, Assoun M, Slama G. Monosodium glutamate affects mealtime food selection in diabetic patients. *Appetite* 1996; 26:267-275
- Bellisle F, Monneuse MO, Chabert M, Larue-Achagiotis C, Lanteaume MT, Louis-Sylvestre J. Monosodium glutamate as a palatability enhancer in the European diet. *Physiol Behav* 1991;49:869-873
- Boucher Y, Berteretche MV, Farhang F, Arvy MP, Azérad J, Faurion A. Taste deficits related to dental deafferentation: an electrogustometric study in humans. *Eur J Oral Sci* 2006;114:456-64
- Chen CC, Schilling LS, Lyder CH. A concept analysis of malnutrition in the elderly. *J Adv Nurs* 2001;36:131-142
- De Graaf C, Polet P, van Staveren WA. Sensory perception and pleasantness of food flavors in elderly subjects. *J Gerontol* 1994;49:93-99
- De Graaf C, van Staveren W, Burema J. Psychophysical and psychohedonic functions of four common food flavors in elderly subjects. *Chem Senses* 1996;21:293-302
- De Jong N, De Graaf C, Van Staveren WA. Effect of sucrose in breakfast items on pleasantness and food intake in the elderly. *Physiol Behav* 1996;60:1453-1462
- Doty RL, Shaman P, Applebaum SL, Giberson R, Siksorski L, Rosenberg L. Smell identification ability: changes with age. *Science* 1984;226:1441-1443
- Essed NH, van Staveren WA, Kok FJ, De Graaf C. No effect of 16 weeks flavor enhancement on dietary intake and nutritional status of nursing home elderly. *Appetite* 2007;48:29-36
- Forde CG, Delahunty CM. Understanding the role cross-modal sensory interactions play in food acceptability in younger and older consumers. *Food Qual Prefer* 2004;15:715-727
- Griep MI, Mets TF, Massart DL. Effects of flavor amplification of Quorn and yoghurt on food preference and consumption in relation to age, BMI and odour perception. *Br J Nutr* 2000;83:105-113
- Griep MI, Mets TF, Vogelaere P, Collys K, Laska M, Massart DL. Odor perception in relation to age, general health, nutritional status, and dental status. *Arch Gerontol Geriatr* 1997;25:263-275
- Johansson A, Hall G, Bengtzon A, Thomas-Danguin T, Rouby C, Sicard G, Vigouroux M, Ormel W, de Graaf C. Development of a new gustatory test based on taste identification and intensity judgment 2004. SIK-Rapport 722. ISBN 91-7290-234-5
- Kapur KK, Soman SD. Masticatory performance and efficiency in dental wearers. *J Prosthet Dent* 1964;14:687-694
- Koskinen S, Kalviainen N, Tuorila H. Perception of chemosensory stimuli and related responses to flavored yogurts in the young and elderly. *Food Qual Prefer* 2003a;14:623-635
- Koskinen, S., Kalviainen, N., Tuorila, H. Flavor enhancement as a tool for increasing pleasantness and intake of a snack product among the elderly. *Appetite* 2003b;41:87-96
- Koskinen S, Tuorila H. Performance on an odor detection and identification test as a predictor of ortho- and retronasal odor intensity ratings in the young and elderly. *Food Qual Prefer* 2005;16:383-392

No effect of flavor enhanced soup on intake in elderly with taste and smell loss

- Kozłowska K, Jeruzska M, Matuszewska I, Roszkowski W, Barylko-Pikielna N, Brzozowska A. (). Hedonic tests in different locations as predictors of apple juice consumption at home in elderly and young subjects. *Food Qual Prefer* 2003;14:653-661
- Kremer S, Bult JHF, Mojet J, Kroeze J. Compensation for age-associated chemosensory losses and its effect on the pleasantness of a custard dessert and a tomato drink. *Appetite* 2007a;48:96-103
- Kremer S, Mojet J, Kroeze JHA. Differences in perception of sweet and savory waffles between elderly and young subjects. *Food Qual Prefer* 2007c;18:106-116
- Lehmann AB, Bassey EJ. Longitudinal weight changes over four years and associated health factors in 629 men and women aged over 65. *Eur J Clin Nutr* 1996;50:6-11
- Löwik MR, Schneijder P, Hulshof KF, Kistemaker C, Sleutel L, van Houten P. Institutionalized elderly women have lower food intake than do those living more independently (Dutch Nutrition Surveillance System). *J Am Coll Nutr* 1992;11:432-440
- Mathey MAM, Siebelink E, De Graaf C, van Staveren WA. (). Flavor enhancement of food improves dietary intake and nutritional status of elderly nursing home residents. *J Gerontol A Biol Sci Med Sci* 2001;56:M200-M205
- Mojet J, Christ-Hazelhof E, Heidema J. Taste perception with age: pleasantness and its relationship with threshold sensitivity and supra-threshold intensity of five taste qualities. *Food Qual Prefer* 2005;16:413-423
- Mojet J, Christ-Hazelhof E, Heidema J. Taste perception with age: generic or specific losses in threshold sensitivity to five basic tastes? *Chem Senses* 2001;26:845-860
- Morley JE. Anorexia of aging: physiologic and pathologic. *Am J Clin Nutr* 1997;66:760-773
- Morley JE. Decreased food intake with aging. *J Gerontol A Biol Sci Med Sci* 2001;56:81-88
- Mowé M, Bøhmer T, Kindt E. Reduced nutritional status in an elderly population (> 70 y) is probable before disease and possibly contributes to the development of disease. *Am J Clin Nutr* 1994;59:317-324
- Murphy C, Withee J. Age and biochemical status predict preference for casein hydrolysate. *J Gerontol* 1987;42:73-77
- Murphy C, Schubert CR, Cruickshanks KJ, Klein BEK, Klein R, Nondahl DM. Prevalence of Olfactory Impairment in Older Adults. *JAMA* 2002;288: 2307-2312
- Newman AB, Yanez D, Harris T, Duxbury A, Enright PL, Fried LP. Weight change in old age and its association with mortality. *J Am Geriatr Soc* 2001;49:1309-1318
- Prescott J, Young A. Does information about MSG (monosodium glutamate) content influence consumer ratings of soups with and without added MSG? *Appetite* 2002;39:25-33
- Sahyoun, N.R., Krall, E. (2003). Low dietary quality among older adults with self-perceived ill-fitting dentures. *J Am Diet Assoc* 2003;103:1494-1499
- Schiffman SS. Perception of taste and smell in elderly persons. *Crit Rev Food Sci Nutr* 1993;33:17-26
- Schiffman SS. Sensory enhancement of foods for the elderly with monosodium glutamate and flavors. *Food Rev Int* 1998;14:321-333

Chapter 3

Schiffman SS, Warwick ZS. Flavor enhancement of foods for the elderly can reverse anorexia. *Neurobiol Aging* 1988;9:24-26

Schiffman SS, Warwick ZS. Effect of flavor enhancement of foods for the elderly on nutritional status: food intake, biochemical indices, and anthropometric measures. *Physiol Behav* 1993;53:395-402

Smith CH, Bidlack WR. Dietary concerns associated with the use of medications. *J Am Diet Assoc* 1984;8:901-914

Stevens JC, Bartoshuk LM, Cain WS. Chemical senses and aging: taste versus smell. *Chem Senses* 1984;9:167-179

Stevens JC, Cruz LA, Hoffman JM, Patterson MQ. Taste sensitivity and aging: high incidence of decline revealed by repeated threshold measures. *Chem Senses* 1995;20:451-459

Thomas-Danguin T, Rouby C, Sicard G, Vigouroux M, Farget V, Johanson A, Bengtzon A, Hall G, Ormel W, De Graaf C, Rousseau F, Dumont JP. Development of the ETOC: a European test of olfactory capabilities. *Rhinology* 2003;41:142-151

Van Strien T, Frijters JER, Bergers GPA, Defares P. The Dutch Eating Behavior Questionnaire (DEBQ) for assessment of restrained, emotional, and external eating. *Int J of Eat Disord* 1986;5:295-315

Wayler AH, Perlmutter LC, Cardello AV, Jones JA, Chauncey HH. Effects of age and removable artificial dentition on taste. *Spec Care Dentist* 1990;10:107-113

Van der Wielen RP, van Heereveld HA, de Groot CP, van Staveren WA. Nutritional status of elderly female nursing home residents; the effect of supplementation with a physiological dose of water-soluble vitamins. *Eur J Clin Nutr* 1995;49:665-674

Wurtman JJ, Lieberman H, Tsay R, Nader T, Chew B. Calorie and nutrient intakes of elderly and young subjects measured under identical conditions. *J Gerontol* 1988;43:B174-180

4

No effect of 16 weeks flavor enhancement on dietary intake and nutritional status of nursing home elderly

Natasja H Essed • Wija A van Staveren • Frans J Kok • Cees de Graaf •
Appetite 2007;48:29-36

ABSTRACT

There is a lack of data to support the long-term effect of flavor enhancement on food intake and nutritional status. Our aim was to determine if daily addition of 700 mg flavor and/or 300 mg monosodium glutamate (MSG) to the animal protein part of the cooked meal for 16 weeks leads to an increase in energy intake and in body weight in nursing home elderly. We performed a single blind randomized 16 weeks parallel study consisting of a control group (n=23), a MSG group (n=19), a flavor group (n=19) and a flavor plus MSG group (n=22). Main outcome measures were intake of the cooked meal, which was measured by weighing back leftovers during 14 days and body weight. Both were measured before and at the end of the intervention period. After 16 weeks, energy intake and body weight did not increase within the control group, the flavor group, the flavor plus MSG group and the MSG group. Between the groups, no differences were found in changes in energy intake and body weight. Enhancing the taste of a cooked meal with flavor and/or MSG does not lead to a higher energy intake and body weight among nursing home elderly. More research is needed to determine the efficacy of flavor enhancement on intake and nutritional status.

INTRODUCTION

Aging seems to be accompanied by a lower energy intake in nursing home residents (Eastwood et al 2002, Lowik et al 1992, Morley 2001 and 1997). Poor energy intake is an important factor related to weight loss in these elderly (Blaum et al 1995) and the latter is associated with higher morbidity and mortality (Chapman et al 2002, Newman et al 2001).

A potential cause of inadequate intake due to a loss of appetite is the impairment of taste and smell performance (Rolls 1999). This loss of taste and smell tends to begin around age 60 and becomes more severe in persons aged 70 and older (Doty et al 1984, Schiffman 1997, Stevens et al 1984).

On average elderly people prefer higher optimal flavor concentrations in certain foods than young people (De Graaf et al 1994, De Graaf et al 1996, Griep et al 1997 and 2000). Griep et al (1997) showed that elderly people preferred high-flavored soup, Quorn and yoghurt while young people favored the low-flavor levels. De Jong et al (1996) found that elderly preferred higher sucrose concentrations in orange lemonade, strawberry jam and strawberry yoghurt but not in chocolate spread and porridge grain. Kozłowska et al (2003) also found that the elders preferred higher sucrose concentrations in apple juice compared to young adults.

Higher flavor intensities can be obtained by boosting the concentration of odor and of taste compounds in foods with flavors (mixtures of odorous molecules extracted from natural products or synthesized) and/or monosodium glutamate (MSG). This approach may hold potential for elderly individuals with diminished sensory function to improve food palatability, intake acceptance and immunity (Schiffman 1998, Schiffman and Warwick 1993).

In theory, higher flavor concentrations are needed to compensate for the lower chemosensory sensitivity in order to obtain a similar optimal perceived intensity (De Graaf et al 1996). However, there is little direct evidence that links the higher optimal flavor concentrations in food to an impaired taste and smell sensitivity in the elderly. Koskinen et al (2003) showed that the olfactory performance of the elderly was not associated with hedonic responses to flavor-enhanced foods.

In a recent 4 months intervention study in a nursing home, Mathey et al (2001) showed that enhancing the taste of cooked meals with flavors plus MSG resulted in a higher food intake at the cooked meal and an increased body weight. Whether the effect of the sensory manipulation was due to the flavors or to MSG is unclear.

Therefore, we studied the effect of adding flavor and/or MSG to the cooked meal separately.

Our aim was to determine whether daily addition of flavor and/or MSG to the animal protein part of the cooked meal for 16 weeks leads to an increase in energy intake of the cooked meal and an increase in body weight. We also determined whether or not the increase in intake was related to olfactory sensitivity.

PARTICIPANTS AND METHODS

Residents from nursing homes, “Liefkenshoek” in Heteren, “Sancta Maria” in Huissen and “Oosterwolde” in Velp, The Netherlands participated in this study. They were told that a 16 week study would be conducted to investigate the effect of a change in taste of their cooked meal. A general questionnaire was used for screening. Inclusion criteria were: aged 65 and older, a resident of the nursing home for more than 3 months, no disease in terminal phase, no allergy to MSG and consuming the cooked meal provided by the nursing home kitchen for at least 5 days a week. After screening, 97 participants were included in the study and provided their written informed consent. The study protocol and all the material provided to the participants were approved by the Medical Ethical Review Committee of Wageningen University.

Design

This single blind study used a 2x2 factorial design with a placebo group and three parallel intervention groups. The residents were unaware to which group they were assigned. The study started with a 2 week run-in period for baseline measurements. Thereafter the participants were randomly assigned to the control group (n=25), the MSG group (n=24), the flavor group (n=26) or to the flavor plus MSG group (n=25) for 16 weeks. Anthropometry data (body weight, body composition), dietary intake of the cooked meal, pleasantness and appetite data were assessed during the run-in period and during the last 2 weeks of the experimental period. Knee height, olfactory sensitivity, depression data and the mini nutritional assessment were assessed during the run-in period.

Flavor enhancement of the cooked meal

The control group received 1 g±0.2 taste- and odorless carrier material (100% maltodextrine). In the MSG group, 1 g±0.2 MSG (30%=300 mg) plus maltodextrine (70%=700 mg) was sprinkled on to the food. The flavor group received 1 g±0.2 of a flavor (70%=700 mg) mixed with maltodextrine (30%=300 mg). In the flavor plus

MSG group, $1 \text{ g} \pm 0.3$ was sprinkled of a flavor (70%=700 mg) mixed with MSG (30%=300 mg).

Nine flavors were used: chicken soup, stewed chicken, fried chicken, roast chicken, stewed pork, roast pork, stewed beef, roast beef and roast lamb (Quest International, Naarden, The Netherlands). Just before meal delivery, appropriate flavors depending on the nature of the animal protein part and by the cooking process, with or without MSG were sprinkled with a spice shaker over the animal protein part (beef, chicken, pork, fish and omelets) to only enhance the natural meat taste of the entree. For fish and omelets, we used a less concentrated mixture of the chicken soup flavor. For the flavor group: 35% chicken soup flavor and 65% maltodextrine and for the flavor plus MSG group: 35% chicken soup flavor, 35% maltodextrine and 30% MSG. The concentration of MSG in our study was equivalent to Mathey et al (2001) $\approx 0.3\%$ MSG/g flavor mix.

Measurements

General questionnaire

This screening questionnaire included questions about medication use, if participants suffered from diseases or had trouble breathing through their nose, used dentures, alcohol use, smoking behavior and sensitivity to MSG.

Anthropometry

Body weight served as an index of the nutritional status before and after the study. We recorded the time of weighing and if participants were measured with or without shoes to meet the same conditions at the end (Seca weighing scale, Hamburg, Germany).

Resistance (R_z , Ohm) and reactance (X_c , Ohm) were measured with bioelectrical impedance analysis (B.C.M. controller, Data Input, Frankfurt, Germany). Total body water, extra cellular water and body fat were calculated using Bodygram 1.1 (Akern Bioresearch, Florence, Italy) to monitor changes.

The knee-to-floor height (KFH) was measured twice without shoes using a stadiometer in a sitting position, from the anterior surface of the thigh to the floor with the ankle and the knee each flexed at a 90° angle against the metallic help. Body height was calculated as follows: height (in cm) $= 3.16 \times \text{KFH (cm)}$ (Berkhout et al 1989).

Dietary intake at the cooked meal

Dietary intake (appetizer, entree and desert) was measured for 14 days by weighing the amount served and leftovers. Our calculations showed that to detect a difference of 200 kJ with a power of 80% we need to measure energy intake for 14 days with 21 participants per group. During the measurement days, individual menus and recipes were obtained from the cook of the nursing home. The dietary data were converted into nutrients using the Dutch food composition table (Nevo 1997).

Pleasantness

Participants were asked to rate the perceived pleasantness of the cooked meal on a 10-point scale during the 14 days of dietary assessment. The left anchor of the scale was explained as not pleasant at all (= 1) and the right anchor corresponded with extremely pleasant (= 10). The elderly are familiar with this type of rating from its use in the Dutch school system.

Olfactory capability

The European test of Olfactory Capabilities (ETOC) (Neurosciences et Systemes Sensoriels, Universite Claude Bernard Lyon 1, France and Healthsense) is based on 16 blocks of four vials and only one vial (15 mL) contains an odor (Thomas-Danguin et al 2003). The odors were: vanilla, cloves, apple, eucalyptus, cinnamon, fuel-oil, pine, garlic, cut grass, anise, orange, fish, rose, thyme, lemon and mint. To evaluate the olfactory performance, a detection task was given followed by an identification task by selecting the right descriptor between the four options.

Cut-off values resulting from 95% confidence limits for different age groups were established upon 1330 participants with the ETOC (Rouby¹). The correct answers from our participants that received a flavor enhancement treatment were compared to these cut-off values according to age. Normal olfactory performance for 70–79 y: detection score is ≥ 14 and identification score is ≥ 10 . Normal olfactory performance for >79 y: detection score is ≥ 13 and identification score is ≥ 8 .

Appetite, hunger feelings and sensory perception questionnaire (AHSP)

Five variables resulted from this questionnaire: present taste perception, 8 items; present smell perception, 3 items, present smell perception compared to the past, 3 items; appetite, 6 items; and daily feelings of hunger, 9 items (Mathey 2001). The questions were read by an interviewer and the participants responded using a 5-point scale. A higher score meant a more positive feeling of their sensory perception, a better appetite and more feelings of hunger.

Geriatric depression scale (GDS)

The GDS assessed the depression status of the participants (Yesavage 1988). It consisted of 15 items to be answered “yes” (1) or “no” (0) that were read to the participant by an interviewer. The answers were summed up to obtain a score. A score above five indicated a depressive status.

Mini nutritional assessment (MNA)

The MNA[®] is a screening and assessment tool for the identification of malnutrition in the elderly (Guigoz and Vellas 1998). In the screening section, a score was calculated which indicated possible malnutrition or not. If so, the assessment section clarified whether the participant was at risk of malnutrition, or if the participant was malnourished.

Statistics

Mean and standard deviations (SD) of baseline and changes were calculated for all the variables per group. A paired t-test was used to compare differences between baseline and end values within groups. One-way analysis of variance (ANOVA) was used to compare changes in variables between groups. Pearson’s correlation coefficient was calculated to determine if the increase in energy intake was related to the olfactory sensitivity. A p value ≤ 0.05 was considered as significant. Data analysis was done with SPSS 11.5 for Windows (SPSS Benelux, Gorinchem, The Netherlands).

RESULTS

Eighty-three out of 97 participants (25 men and 58 women) completed the study. Fourteen participants were dropped because of death (4), taste dislike of the added flavor (1), change to drip-feed (1), admittance to the hospital (2), relocation (2), not wanting to complete the measurements (1) and personal reasons (3). Dietary intake data was obtained from everybody and body weight from 82 participants. Seventy-seven participants were able to understand and answer the questions from the GDS and AHSP. Data on the MNA and body composition were obtained from 75 and 79 participants, respectively.

Baseline characteristics

The four intervention groups were comparable regarding the baseline characteristics and reported diseases such as diabetes, cardiovascular disorders and digestive track disorders. The participants were not depressed during the study (mean GDS score: 3.5). Compliance was high; subjects consumed the cooked meal on average 105 of 112 days during the intervention period (94%) (Table 1).

Table 1. Baseline characteristics of the four intervention groups of nursing home elderly

Variable	Control group (n=23)	Flavor group (n=19)	Flavor plus MSG group (n=22)	MSG group (n=19)
Age [mean (SD) years]	85.6 (8.5)	85.4 (6.7)	84.9 (6.2)	84.9 (5.7)
Gender (male/female)	8/15	6/13	5/17	6/13
Living with spouse	1	2	6	4
Dentures (%)				
Complete	73.9	68.4	68.2	73.7
Partial	8.7	21.1	18.2	21.1
None	17.4	10.5	13.6	5.3
Smoking behavior (%)				
No smoking	78.3	89.5	90.9	78.9
Smoking	21.7	10.5	9.1	21.1
Restrained physical mobility (% use)				
Wheel chair	17.4	36.8	22.7	31.6
Walking frame	56.5	68.4	77.3	73.7
Medicine uses [mean number/day (SD)]	4.1 (3.6)	5.2 (2.8)	4.9 (3.5)	5.4 (3.1)
GDS score [mean (SD)] ^{a,b}	2.9 (2.8)	2.7 (1.7)	4.0 (2.2)	4.2 (2.5)
MNA: Risk of malnutrition (%) ^{c,d}				
No risk	68.4	76.5	75	66.7
Increased risk	31.6	23.5	25	33.3
Protein energy malnutrition	0	0	0	0

^aGDS= Geriatric Depression Scale; ^bcontrol group (n=21), flavor group (n=17), flavor plus MSG group (n=21), MSG group (n=18); ^cMNA= Mini Nutritional Assessment (Normal score≥23.5, Maximum score=30); ^dcontrol group (n=19), flavor group (n=17), flavor plus MSG group (n=20), MSG group (n=1)

Anthropometry

The four groups were comparable regarding all the baseline anthropometric characteristics. We found no change in body weight within the control group (0±4 kg, p=0.88), the flavor group (0±2 kg, p=0.85), the flavor plus MSG group (-1±3 kg, p=0.30) and the MSG group (-1±4 kg, p=0.39). Body fat, total body water and extra cellular water did not change within any of the four groups. Between the four groups,

the changes in body weight ($p=0.71$), body fat ($p=0.54$), total body water ($p=0.40$) and extra cellular water ($p=0.50$) were not significantly different (Table 2).

Table 2. Anthropometry characteristics and changes after 16 weeks [mean (SD)] of the four intervention groups of nursing home elderly

Variable	Control group n=23	Flavor group n=19	Flavor plus MSG group n=22	MSG group n=19
Body weight (kg) at baseline	69.3 (14.9)	74.3 (15.6)	73.2 (16.1)	71.7 (14.2)
Change ^a	0.1 (3.8)	0.1 (2.4)	-0.8 (3.3)	-0.7 (3.6)
Calculated Height (cm) ^b at baseline	159.5 (11.5)	161.6 (10.2)	160.3 (9.7)	161.2 (9.7)
Body mass index (kg/m ²) at baseline	27.2 (5.1)	28.5 (5.8)	28.3 (4.3)	27.5 (4.4)
Body fat (kg) at baseline ^c	24.9 (9.9)	29.4 (10.7)	29.8 (8.3) b	28.5 (11.2)
Change ^d	0.1 (2.7)	-0.6 (2.8)	0.3 (2.6)	-0.7 (3.4)
Total body water (L) at baseline ^c	35.5 (6.9)	36.6 (7.6)	36.7 (6.9)	34.5 (5.5)
Change ^d	0.04 (1.9)	-0.006 (1.6)	-0.8 (2.2)	-0.01 (0.8)
Extra cellular water (L) at baseline ^c	20.5 (4.2)	21.1 (4.2)	21.1 (4.9)	20.3 (4.3)
Change ^d	0.2 (1.5)	-0.1 (2.2)	-0.7 (2.1)	0.04 (1.7)

^bBerkhout 1989; ^aflavor plus MSG group (n=21); ^cflavor group (n=17) and flavor plus MSG group (n=20); ^dcontrol group (n=22), flavor group (n=17) and flavor plus MSG group (n=19)

Dietary intake at the cooked meal

The four groups were comparable regarding baseline values for energy intake (kJ) and other macronutrients. After 16 weeks of intervention, energy intake did not change within the control group (102 ± 452 kJ, $p=0.29$), the flavor group (-17 ± 445 kJ, $p=0.87$), the flavor plus MSG group (78 ± 352 kJ, $p=0.31$) and the MSG group (-32 ± 283 kJ, $p=0.63$). Total protein increased within the control group (4 ± 7 g, $p=0.007$) and the flavor plus MSG group (3 ± 5 g, $p=0.03$) but not within the flavor and the MSG group. Carbohydrate decreased within the flavor group (-3 ± 6 g, $p=0.04$) but did not change within the other groups. Between the four groups, changes in energy intake ($p=0.61$), total protein ($p=0.18$), carbohydrate ($p=0.89$) and fat ($p=0.83$) intake were not significantly different (Table 3).

Chapter 4

Meat consumption (g) and the animal protein intake (g) (beef, chicken, pork, fish and omelets) were analyzed from dietary intake data and their baseline values were comparable between the four groups. After 16 weeks, meat consumption decreased in the flavor group (-7 ± 12 g, $p=0.03$) but not within the other groups. Animal protein intake increased slightly in the control group (2 ± 4 g, $p=0.01$) but did not change within the other groups. Changes in meat consumption ($p=0.18$) and animal protein intake ($p=0.06$) were not different between the four groups (Table 4).

Table 3. Mean baseline values (SD) of energy and macronutrient intake and changes after 16 weeks of the cooked meal of the four intervention groups of nursing home elderly

Variable	Control group (n=23)			Flavor group (n=19)			Flavor plus MSG group (n=22)			MSG Group (n=19)		
	Baseline	Change		Baseline	Change		Baseline	Change		Baseline	Change	
Energy (kJ)	2150 (559)	102 (452)		2208 (479)	-17 (445)		2238 (526)	78 (352)		2267 (533)	-32 (283)	
Total protein (g)	28 (7)	4 (7) ^a		29 (7)	1 (6)		28 (7)	3 (5) ^a		29 (8)	1 (5)	
Carbohydrate (g)	54 (16)	-1 (10)		54 (16)	-3 (6) ^a		57 (16)	-2 (5)		57 (18)	-3 (8)	
Fat (g)	20 (6)	2 (7)		21 (6)	1 (10)		21 (6)	2 (6)		21 (7)	0 (6)	

^aSignificant difference in changes within one group between start and end of the intervention period; p<0.05

Table 4. Mean baseline values (SD) and changes after 16 weeks of meat consumption (g) (chicken, fish, pork, beef and omelettes) and animal protein intake (g) of the cooked meal of four intervention groups of nursing home

Variable	Control group (n=23)			Flavor group (n=19)			Flavor plus MSG group (n=22)			MSG Group (n=19)		
	Baseline	Change		Baseline	Change		Baseline	Change		Baseline	Change	
Meat consumption (g)	74 (22)	2 (16)		77 (26)	-7 ^a (12)		78 (21)	-1 (13)		78 (19)	-6 (14)	
Animal protein intake (g)	17 (5)	2 ^a (4)		17 (4)	0 (3)		16 (4)	1 (3)		17 (4)	0 (4)	

^aSignificant difference in changes within one group between start and end of the intervention period; p<0.05

Olfactory sensitivity and changes in energy intake

Forty-eight out of 60 participants that were exposed to a flavor enhancement treatment were able to understand and perform the ETOC. According to the cut-off values for different age groups, 23% of all these participants had normal olfactory performance (n=11) and 77% had low olfactory performance (n=37). Figure 1 shows the result of the change in energy intake (kJ) as a function of the ETOC score (correct detection scores plus correct identification scores) for the participants with normal and low olfactory performance. The Pearson correlation coefficient (r) was -0.29 and is significant at $p=0.047$ meaning that a lower olfactory performance was related to a higher (positive) change in energy intake.

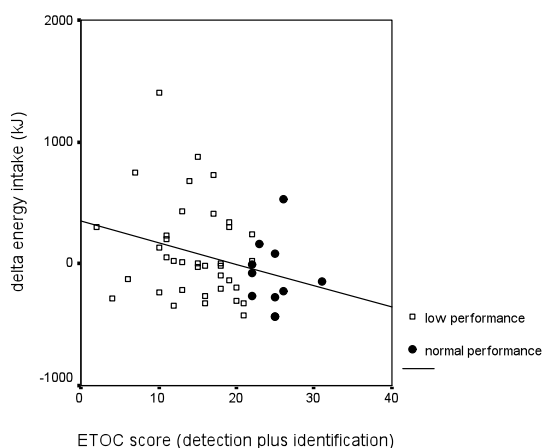


Figure 1. Delta energy intake (kJ) as a function of the ETOC score (correct detection scores plus correct identification scores, range =0 to 32) for the elderly participants that received a flavour enhancement treatment (n=48) with normal ([●] n=11) and low ([■] n=37) olfactory performance.

Appetite, Hunger feelings and Sensory Perception (AHSP) questionnaire and pleasantness of the cooked meal

No differences were found between baseline values except for the variable present smell perception compared to the past ($p=0.04$). After 16 weeks of intervention, ratings for present taste perception decreased in the flavor group (-2.1 ± 3.5 , $p=0.03$). Between the four groups, changes in appetite ($p=0.53$), feelings of hunger ($p=0.89$), taste perception ($p=0.54$), smell perception ($p=0.86$), smell perception to the past ($p=0.39$) and pleasantness of the cooked meal ($p=0.60$) were not different.

DISCUSSION

The purpose of this study was to determine whether daily addition of appropriate flavors, flavors plus MSG or MSG alone to the cooked meal for 16 weeks would lead to an increased energy intake at the cooked meal and a concurrent change in body weight. And if so, whether the increase in energy intake was related to olfactory sensitivity. Based on the results found by Mathey et al (2001), we expected that the addition of flavors plus MSG would lead to a higher energy intake and a higher body weight.

However, no increase in energy intake at the cooked meal and no increase in body weight were found within any of the four intervention groups in this study. The changes in energy intake and body weight were also not different between the four intervention groups. In this study, the changes in energy intake were negatively related to olfactory sensitivity among the subjects that were exposed to a flavor enhancement treatment.

The taste of the animal protein component of the cooked meal in this study was enhanced with specific flavors and/or MSG. Perhaps enhancing the taste of just one component of the cooked meal was insufficient to observe an effect on energy intake. Just as Mathey et al (2001) 1 g of flavor with 30% MSG in the flavor plus MSG group was sprinkled in this study. Mathey sprinkled the flavor plus MSG on to the whole cooked meal including the carbohydrate rich components and the vegetables. This changed the taste of the carbohydrates and the vegetables as well. Possibly the combination of the altered taste of starch and vegetables, together with the enhanced taste of the meats caused the increase in energy intake and body weight in their study.

Another possible explanation for our findings is that the MSG dosage (300 mg over an average of 100 g of animal protein= 0.3%) in our study was wrong. Higher (but not significant) intake of the soup with MSG compared with plain soup was found with 0.362% in beef consommé (Rogers and Blundell 1990) and 0.4% in vegetable soup (Beauchamp et al 1987). Bellisle et al (1991) added 0.6% MSG to two soups, mashed potatoes and rice as part of a menu during a 6-month study with elderly people. Only mushroom soup and mashed potatoes intake increased and total energy of the whole menu remained the same. The intake of starch foods to which 0.6% MSG was added every week during four weeks, was higher among diabetic elderly in the MSG group compared to the no MSG group (Bellisle et al 1996). Schiffman (1998) showed that a combination of 0.3–1.0% MSG and flavor for a week improved energy intake by 10% or more in 40 out of 43 sick elderly but it is unclear

which foods she used to enhance. Prescott and Young (2002) found that subjects showed a greater increase in liking of vegetable soup with 0.8% MSG compared to soup without MSG. Based on these results we selected 300 mg of MSG but we do not exclude that a higher dosage would have been more effective to increase energy intake.

Our study population had a relatively high age (85 yrs) which may cause them to be less sensitive to changes in flavor concentration. This could have intervened with the ability to detect a difference in taste with the dosage we used. Increasing MSG and therefore sodium levels on the other hand is not desirable, as many residents may need sodium-controlled diets.

The participants in this study were selected based on the effects on body weight found by Mathey et al (2001). Despite the fact that they had a mean age of 85 yrs and that 30% were at risk of malnutrition we found no effect of flavor enhancement on intake and body weight. As they had a lower mean energy intake than recommended, our population was perhaps in a suboptimal nutritional condition. Nursing home elderly are a vulnerable group and we therefore consider them as an appropriate target group for flavor enhancement.

The use of medicine in our population, though those participants were excluded which were on medication known to affect appetite or their taste and smell performance, affirms that diseases were present which could have affected their intake in another way. They may have had diseases resulting in a reduced salivary flow and particularly polypharmacy, with xerostomia as a side effect. These issues might also intervene with the response to the flavor enhancement.

The fact that 70% of our population wore complete dentures and 17% had partial dentures could have affected food intake in several ways. Although not assessed in our study, ill-fitting dentures may cause low dietary quality and intake (Sahyoun and Krall 2003). Complete denture wear affects masticatory ability which could also have contributed to our finding (Kapur and Soman 1964). Partial denture wear is also found to be associated with decreased odor perception and the latter is an important determinant of food intake (Griep et al 1997). For older persons with partial or complete dentures, Wayler et al (1990) found higher recognition thresholds for sodium chloride so the tasting of salt becomes more difficult. Most likely all of the issues mentioned above, contributed to our findings.

Olfactory sensitivity and changes in energy intake

It was expected that elderly people with a low olfactory performance when exposed to a flavor enhancement treatment, to have an increased intake of food (possibly because of more appreciation for the flavor-enhanced food) compared with the elderly with a normal performance. The finding that delta energy intake was negatively related to olfactory sensitivity (ETOC score = detection plus identification) confirmed this expectation. This finding needs to be replicated in order to add a flavor enhancer to foods for elderly with low olfactory performance.

The effect of flavor enhancement on intake and body weight seems more complex than expected at first. For some elderly flavor amplification may hold potential because the changes in energy intake for people with low olfactory scores were larger than for people with normal olfactory scores but not for all. This could be because the elderly are such a heterogeneous group. In general, there is more to consider when flavor enhancement is used such as the right population, the use of medication, denture wear and whether participants can actually taste the difference between flavor-enhanced and non-enhanced food and find it more palatable. If the latter is not the case, flavor enhancement is of no use.

CONCLUSION

Enhancing the taste of the animal protein part of a cooked meal by daily addition of 700 mg flavor and/or 300 mg MSG does not lead to higher energy intake, animal protein intake and body weight among nursing homes residents.

REFERENCES

- Beauchamp GK, de Vaquera MV and Pearson PB. Dietary status of human infants and their sensory responses to amino acid flavor. 1987. In Y Kawamura and MR Kare (Eds.), *Umami: A basic taste* (pp. 125–138). New York: Marcel Dekker
- Bellisle F, Dalix AM, Chappuis AS, Rossi F, Fiquet P, Gaudin V, et al. Monosodium glutamate affects mealtime food selection in diabetic patients. *Appetite* 1996;26:267–275
- Bellisle F, Monneuse MO, Chabert M, Larue-Achagiotis C, Lanteaume MT, Louis-Sylvestre J. Monosodium glutamate as a palatability enhancer in the European diet. *Physiol Behav* 1991;49:869–873
- Berkhout AM, Cools HJ, Mulder JD. Measurement or estimation of body length in older nursing home patients. *Tijdschrift voor Gerontologie en Geriatrie* 1989;20:211–214
- Blaum CS, Fries BE, Fiatarone MA. Factors associated with low body mass index and weight loss in nursing home residents. *J Gerontol: Med Sci* 1995;50:M162–M168
- Chapman IM, MacIntosh CG, Morley JE, Horowitz M. *Biogerontology* 2002;3:67–71
- De Graaf C, Polet P, van Staveren WA. Sensory perception and pleasantness of food flavors in elderly subjects. *J Gerontol A Biol Sci Med Sci* 1994;49:93–99
- De Graaf C, van Staveren W, Burema J. Psychophysical and psychohedonic functions of four common food flavors in elderly subjects. *Chem Senses* 1996;21:293–302
- De Jong N, De Graaf C, van Staveren WA. Effect of sucrose in breakfast items on pleasantness and food intake in the elderly. *Physiol Behav* 1996;60:1453–1462
- Doty RL, Shaman P, Applebaum SL, Giberson R, Siksorski L, Rosenberg L. Smell identification ability: Changes with age. *Science* 1984;226:1441–1443
- Eastwood C, Davies GJ, Gardiner FK, Dettmar PW. Energy intakes of institutionalized and free-living older people. *J Nutr Health Aging* 2002;6:91–92
- Griep MI, Mets TF, Massart DL. Different effects of flavour amplification of nutrient dense foods on preference and consumption in young and elderly subjects. *Food Qual Prefer* 1997;8:151–156
- Griep MI, Mets TF, Massart DL. Effects of flavor amplification of Quorn and yoghurt on food preference and consumption in relation to age, BMI and odour perception. *Br J Nutr* 2000;83:105–113
- Griep MI, Mets TF, Vogelaere P, Collys K, Laska M, Massart DL. Odor perception in relation to age, general health, nutritional status, and dental status. *Arch Gerontol Geriatr* 1997;25:263–275
- Guigoz Y, Vellas B. Assessing the nutritional status of the elderly: The Mini Nutritional Assessment as part of the geriatric evaluation. *Nutr Rev* 1998;54:S59–S65
- Kapur KK, Soman SD. Masticatory performance and efficiency in dental wearers. *J Prosthet Dent* 1964;14:687–694
- Koskinen S, Kalviainen N, Tuorila H. Flavor enhancement as a tool for increasing pleasantness and intake of a snack product among the elderly. *Appetite* 2003;41:87–96

Kozłowska K, Jeruszka M, Matuszewska I, Roszkowski W, Barylko-Pikielna N, Brzozowska A. Hedonic tests in different locations as predictors of apple juice consumption at home in elderly and young subjects. *Food Qual Prefer* 2003;14:653–661

Lowik MR, van den Berg H, Schrijver J, Odink J, Wedel M, van Houten P. Marginal nutritional status among institutionalized elderly women as compared to those living more independently (Dutch Nutrition Surveillance System). *J Am Coll Nutr* 1992;11:673–681

Mathey MF. Assessing appetite in Dutch elderly with the Appetite, Hunger and Sensory Perception (AHSP) questionnaire. *J Nutr Health Aging* 2001;5:22–28

Mathey MAM, Siebelink E, De Graaf C, van Staveren WA. Flavor enhancement of food improves dietary intake and nutritional status of elderly nursing home residents. *J Gerontol Med Sci* 2001;56A:M200–M205

Morley JE. Anorexia of aging: physiologic and pathologic. *Am J Clin Nutr* 1997;66:760–773

Morley JE. Decreased food intake with aging. *J Gerontol A Biol Sci Med Sci* 2001;56A:81–88

Nevo. Stichting Nederlands voedingsstoffenbestand. Dutch Nutrient Database 1997. The Hague, The Netherlands: Voorlichtingsbureau voor de voeding

Newman AB, Yanez D, Harris T, Duxbury A, Enright PL, Fried LP. Weight change in old age and its association with mortality. *J Am Geriatr Soc* 2001;49:1309–1318

Prescott J, Young A. Does information about MSG (monosodium glutamate) content influence consumer ratings of soups with and without added MSG? *Appetite* 2002;39:25–33

Rogers PJ, Blundell JE. Umami and appetite: Effects of monosodium glutamate on hunger and food intake in human subjects. *Physiol Behav* 1990;48:801–804

Rolls BJ. Do chemosensory changes influence food intake in the elderly? *Physiol Behav* 1999;66:193–197

Sahyoun NR, Krall E. Low dietary quality among older adults with self-perceived ill-fitting dentures. *J Am Diet Assoc* 2003;103:1494–1499

Schiffman SS. Taste and smell losses in normal aging and disease. *JAMA* 1997;278:357–362

Schiffman SS. Sensory enhancement of foods for the elderly with monosodium glutamate and flavors. *Food Rev Int* 1998;14:321–333

Schiffman SS, Warwick ZS. Effect of flavor enhancement of foods for the elderly on nutritional status: Food intake, biochemical indices, and anthropometric measures. *Physiol Behav* 1993;53:395–402

Stevens JC, Bartoshuk LM, Cain WS. Chemical senses and aging: Taste versus smell. *Chem Senses* 1984;9:167–179

Thomas-Danguin T, Rouby C, Sicard G, Vigouroux M, Farget V, Johanson A, et al. Development of the ETOC: A European test of olfactory capabilities. *Rhinology* 2003;41:142–151

Wayler AH, Perlmutter LC, Cardello AV, Jones JA, Chauncey HH. Effects of age and removable artificial dentition on taste. *Spec Care Dentist* 1990;10:107–113

Yesavage JA. Geriatric depression scale. *Psychopharmacol Bull* 1988;24:709–711

5

Optimal preferred MSG concentration in potatoes, spinach and beef and their effect on intake in institutionalized elderly people

Natasja H Essed • Patty Oerlemans • Martine Hoek • Wija A van Staveren •
Frans J Kok • Cees de Graaf • **J Nutr Health Aging 2009;13:769-775**

ABSTRACT

Elderly people may benefit from sensory stimulation to increase food intake since anorexia of ageing is prevalent among them. An optimal MSG concentration may increase the palatability of foods but this depends on the food and chemosensory status of the taster. Currently, the results on taste enhancing to increase intake are inconsistent. Therefore, this two-fold study was performed to find an optimal preferred MSG concentration in mashed potatoes, spinach and ground beef and to determine whether this concentration increases consumption of these foods among institutionalized elderly people. In the sensory study, 33 elderly and 29 young people rated pleasantness (10-point scale) of the 3 foods each with 0 g, 0.5 g, 0.8 g, 1.3 g and 2.0 g of MSG/100 g. In the intake study, 53 elderly received 2 cooked meals with MSG (0.5% in mashed potatoes, 2% in spinach and ground meat) and without MSG in random order (single blind, cross-over design) within four weeks. Intake was measured by weighing back leftovers. The sensory study showed that 0.5% MSG ($p < 0.05$) was preferred in mashed potatoes but no optimal preferred concentration was found for spinach and ground beef, possibly because of their complex taste. Intake (g and kJ) was not different between the food items with and without MSG or the total meal (all $p > 0.68$). In conclusion, MSG (0.5% and 2%) does not guarantee a higher intake among elderly. The chemosensory heterogeneity of the elderly population requires more individual flavor enhancement to improve the dietary intake and sensory experience.

INTRODUCTION

Gradual loss of smell and taste perception is common among elderly people (Stevens et al 1995, Ship and Weiffenbach 1993, Schiffman 1993). Overall, the sense of smell is more affected than the sense of taste (Stevens et al 1984). Since both senses play a major role in the palatability of food (Rolls 1993), the enjoyment and as a consequence the intake may decline because of the changes in chemosensory function (Rolls 1999). This could lead to body weight loss and a poor nutritional status (Rolls 1999).

Previous studies suggest that MSG (mono sodium glutamate) improves the pleasantness and intake of food (Schiffman and Warwick 1988 and 1993, Schiffman et al 1994, Schiffman 1998, Prescott and Young 2002, Murphy 1987). The optimal concentration of MSG differs for each food product. For example, Bellisle et al (1991) showed that 0.6% MSG increased the intake of mushroom soup and mashed potatoes but not of rice. They also demonstrated that 0.6% MSG increased the intake of pasta and semolina but not of vegetables such as green beans, celery and cauliflower (Bellisle et al 1996). Further, this group showed that a concentration of 1.2% MSG added to beef jelly and spinach mousse caused an immediate increased consumption but no sustained higher intake (Bellisle et al 1989). Lastly, Yamaguchi and Takahashi (1984) found optimum MSG concentrations of 0.3% in clear soup, 0.3% in egg custard and 0.9% in miso soup.

Elderly people prefer higher MSG concentrations in various food items compared to young adults. Murphy (1987) found higher preferred MSG levels for older people when 0-0.5% MSG was added to soup. In younger people, Schiffman and Miletic (1999) found optimal concentrations of 0.3% MSG in corn, 0.15% in carrots, 0.6% in chicken broth and 0.8% in onion soup while these concentrations were at least 10 times higher in corn and carrots, 2.0% in chicken broth and 1.5% in onion soup for elderly people. However, it is unclear in this last study how these optimal concentrations were determined.

The objective of the two-fold study reported here is to determine whether or not an optimal preferred MSG concentration in several foods increases intake in elderly people. In the sensory study we sought for an optimal preferred concentration of MSG in several food items for young and elderly using MSG concentrations varying from 0.5%-2.0% w/w. In the intake study we examined the effect of the obtained optimal concentrations on intake in elderly participants.

PARTICIPANTS AND METHODS

The sensory study included elderly people who were residents of nursing home “Dorpsveld” in Rotterdam, the Netherlands. The young adults were recruited by advertisements in Wageningen University buildings. The intake study included only elderly people, recruited from 3 nursing homes in Deventer, Gendringen and Rijssen, the Netherlands.

A general questionnaire was used for screening. The inclusion criteria for the elderly were: ≥ 65 yrs, able to participate in a sensory study, good eyesight, no allergy to MSG or the foods in this study, not on a sodium restricted diet, no disease in terminal phase and no use of antidepressants. The criteria for the young adults were: < 30 yrs of age and not allergic to MSG or to the foods in this study. After screening, 39 elderly and 29 young people were enrolled in the sensory study and 58 elderly participated in the intake study. Everyone provided their written informed consent. The Medical Ethical Committee of the Division of Human Nutrition of Wageningen University approved the study protocol plus the used materials.

Design

The sensory study started with a 1-day pilot experiment to select three suitable foods and to determine the adequate MSG concentration range to use in the main sensory study. For the latter experiment, the participants were divided over 6 test sessions and rated 15 food samples (3 foods each with 5 MSG concentrations). The intake study had a within subject cross over design and lasted 4 weeks. Once a week on the same day the elderly people received a hot meal using the 3 foods from the sensory study, either with or without MSG. Everyone received 2 meals with MSG and 2 meals without MSG in random order. The olfactory performance and the nutritional status (of the elderly) were assessed in both studies. The studies were carried out single blind.

Stimuli

The pilot experiment was conducted with 5 young participants and 5 foods i.e. mashed potatoes (potato powder, Maggi, Nestlé), frozen spinach, minced meat, cream of mushroom soup and bread. All products were tested with 0, 0.5, 0.8, 1.3 and 2.0 g of MSG (Spice Island, Koninklijke Euroma BV, Wapenveld, the Netherlands)/100 g of product (0.2 log steps), except for bread, which was tested with 0, 0.5, 2.0 and 3.0 g of MSG/100 g of product. Half of the normal salt levels were used in the food products. When adding MSG to a product, less salt could be used without the loss of palatability (Roininen et al 1996). The reduced added salt levels were 0.2 g salt (NaCl)/100 g in the mashed potatoes (0.07 g of salt in the powder -

could not be reduced- and 0.13 added during the preparation), 0.25 g salt/100 g in spinach and 0.37 g of salt in minced meat (Henderson et al 1999).

Mashed potatoes, minced meat and spinach were found suitable for the sensory and the intake study plus they make up an appropriate hot meal in a Dutch nursing home. The MSG range appeared to be wide enough because the concentrations showed clear effects on the perceived pleasantness ratings (especially in mashed potatoes and minced meat) and the intensity (in all products). Thus, mashed potatoes (0.2 g NaCl/100 g), spinach (0.25 g NaCl/100 g) and minced meat (0.37 g NaCl/100 g) were included, each with 0 g, 0.5 g, 0.8 g, 1.3 g and 2.0 g of MSG/100 g. The preferred MSG concentrations for the elderly as determined in the sensory study (0.5% MSG in mashed potatoes (optimal), 2% in minced meat and 2% MSG in spinach) were used in the intake study. For minced meat 2% was chosen because the pleasantness ratings increased upon higher MSG concentrations and was highest at 2%. Spinach, as well as minced meat has a complex taste; therefore a substantial amount was needed to make up a sensory difference between the regular and the MSG enriched spinach.

Procedure

The foods in both studies were prepared according to a standard recipe (Henderson et al 1999). For the sensory study, the foods were prepared in the nursing home kitchen except for minced meat which was prepared in the university research kitchen 2 days before testing and refrigerated at approx. 5 °C. Before each test session, the reheated meat (3 minutes at 900 Watt) and other foods were mixed with an appropriate amount of MSG. All foods were kept warm in aluminum boxes with cardboard lids (labeled with or without MSG in the intake study) au bain-marie (Hufner, Munster, Germany).

For tasting and rating of the food samples, the elderly participants of the sensory study were seated at separate tables in a room ($\pm 18 \text{ m}^2$) in the nursing home. The young people were seated in sensory test cabins in the university laboratory. Everyone was instructed not to talk. The researchers checked this by being present in the room of the nursery home as well as in the laboratory. Approximately 40 g of each sample (65 °C) was served in labeled plastic cups with plastic spoons with a 2 minute interval for the elderly and 1 minute for the young people. The order of the food products was randomized between the 6 test sessions and the order of the MSG concentrations was randomized within the test sessions.

In the intake study, some elderly were seated in a living room while others stayed in their apartment. These conditions did not change during the study. On a warm plate (\varnothing 25 cm), 300 g (Denver Instrument/XP-3000, round off in 0,1 g) of spinach, 300 g of mashed potatoes and 200 g of minced meat were weighted and put on a tray with a cup of broth (bouillon) and a dessert (yogurt). All the meals, with or without MSG were delivered at the same time every day.

Measurements

Anthropometry

In both studies, the knee-to-floor height (KFH) of the elderly participants was measured twice without shoes using a stadiometer in a sitting position, from the anterior surface of the thigh to the floor with the ankle and the knee each flexed at a 90° angle against the metallic help. Body height was calculated as follows: height (in cm) = 3.16*KFH (cm) (Berkhout et al 1989). Body weight was measured using a weighing scale (Seca, Hamburg, Germany).

Sensory evaluation of taste intensity and pleasantness (sensory study)

Taste intensity and pleasantness of the 3 foods with varied MSG concentrations were rated on a 10-point scale by the taste and swallow method. Dutch elderly are familiar with this scale because it is used in the Dutch school system. The left anchors (=1) were marked 'not at all' and the right anchors (=10) 'extremely' for each attribute. After each sample, participants neutralized their taste with tap water.

Dietary intake of the hot meal (intake study)

The portion sizes were twice as large compared to normal sizes so the elderly could eat ad libitum. Intake was measured by weighing the left-overs of each component (minced meat, spinach and mashed potatoes) together and separately. The data were converted into nutrients and energy using the Dutch food composition table (Nevo 1997).

Mini Nutritional Assessment (MNA)

The MNA[®] is a screening and assessment tool to identify malnutrition in the elderly (Guigoz et al 1996). A calculated score from the screening section indicates possible malnutrition or not. If so, the questions of the assessment section plus two anthropometric measures namely mid arm circumference and calf circumference clarify whether the participant is at risk of malnutrition, or if the participant is malnourished. The MNA was administered to the elderly people.

Olfactory capability

The European test of Olfactory Capabilities (ETOC) (Neurosciences et Systemes Sensoriels, Universite Claude Bernard Lyon 1, France and Healthsense) measured olfactory sensitivity for common odorants. The test contains sixteen blocks of four vials and only one vial (15 mL) contains an odor (Thomas-Danguin et al 2003). The odors are: vanilla, cloves, apple, eucalyptus, cinnamon, fuel-oil, pine, garlic, cut grass, anise, orange, fish, rose, thyme, lemon and mint. To evaluate the olfactory performance, a detection task was given followed by an identification task by selecting the right descriptor between the four options. A correct identification answer was only included when the correct accompanying detection answer was given. The ETOC score (maximum score=32) is the sum of the correct detection score and the correct identification score.

Cut-off values resulting from 95% confidence limits for different age groups were established upon 1330 participants with the ETOC (Rouby,¹). The correct answers from our participants were compared to these cut-off values according to age. Normal scores for the young subjects (20-29 y) were 16 for detection and ≥ 14 for identification. Normal scores for 70-79 y: detection score ≥ 14 and identification score ≥ 11 . For ≥ 80 y: detection score ≥ 13 and identification score ≥ 9 .

Statistics

For the sensory study, a within-subjects repeated measures design (ANOVA) compared mean attribute ratings measured at 5 different MSG concentration levels. Age served as a between-subject factor and concentration as a within-subject factor. With the cutoff values derived from results of the ETOC, participants within both age groups were divided into a group with low and normal olfactory performance. ANOVA compared pleasantness ratings measured at the 5 MSG levels between the low and normal group.

The Wilcoxon Signed Rank Test compared differences in mean intake between the hot meals with and without MSG. The data of the intake study was not normally distributed and intake was measured within the same subject. A Pearson correlation coefficient determined if the change in energy intake was related to the ETOC score.

All statistical analyses were performed with SPSS for WINDOWS software (version 11.5; SPSS Benelux, Gorinchem, The Netherlands). *P* values < 0.05 were considered significant.

RESULTS

Thirty-three elderly out of 39 completed the sensory study. Six dropped out, because of health (4) and personal reasons (2). All 29 young participants completed the study. Dietary intake data of 53 out of 59 elderly were included in the analysis of the intake study. Six people dropped out, 4 did not like the hot meal, 1 person consumed only one meal and the last participant did not save the left-overs. Of the 53 participants, 87% ate all the 4 meals and 13% consumed 2 or 3 meals with at least one hot meal of both conditions.

General characteristics and olfactory performance

The general characteristics of the participants of both studies are given in Table 1. The percentage of elderly wearing dentures was 82 in the sensory study versus 96% in the intake study. The elderly participants had lower ETOC scores with a higher variation (figure 1) compared to the young adults.

Table 1. Characteristics of the young and the elderly participants of the sensory study and the intake study (mean & SD)

Characteristic	Sensory study		Intake study
	Young (n=29)	Elderly (n=33)	Elderly (n=53)
Gender (male/female)	6/23	12/21	13/40
Age (y)	21.3 (2.2)	80.8 (6.2)	85.8 (6.2)
Height (m)	1.74 (0.1)	1.65 (0.1)	1.61 (0.1)
Weight (kg)	64.4 (8.0)	74.6 (14.1)	68.3 (11.0)
BMI (kg/m ²)	21.3 (2.0)	27.4 (4.9)	26.5 (4.2)
Dentures (%) ¹	4	82	96
Smoking (yes/no) (%)	10/90	9/91	2/98
MNA: risk of malnutrition (%) ²			
No risk	-	79	85
Increased risk		21	11
Malnutrition		0	4
ETOC score ³	28.1 (1.9)	20.0 (7.7)	12.0 (7.5)
ETOC score/max score (%) ⁴	88	63	38
Participants with normal ETOC score for age (%) ⁵	21	33	0.0

¹Sensory study participants: denture wear not subdivided into complete or partial wear.

²MNA = Mini Nutritional Assessment. Normal score ≥ 23.5 (maximum score = 30)

³ETOC score= sum of the correct detection score and the correct identification score of the European Test of Olfactory Capabilities. (Range: 0-32)

⁴Mean ETOC score divided by the maximum score (32)

⁵Percentage of young or elderly people with normal ETOC score according to cut off values for age

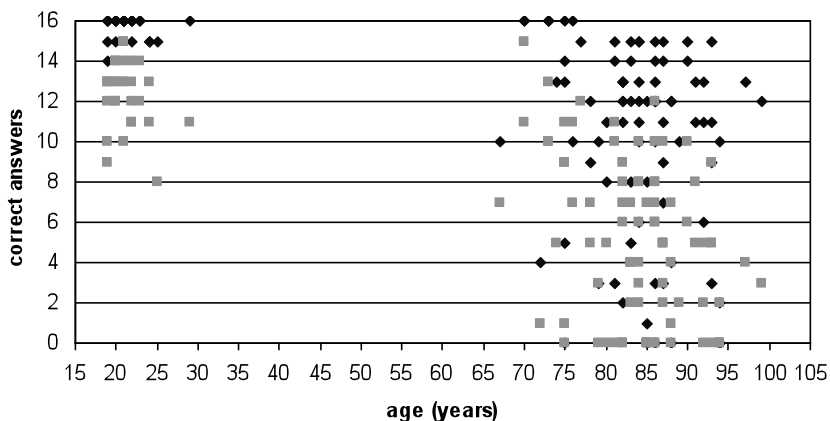


Figure 1. Correct detection (◆) and identification (■) responses (both with max score of 16) of the young (n=29) and all the elderly (n=33 in sensory study; n=53 in intake study) in the European Test of Olfactory Capabilities as a function of age

Sensory study

Effect 0-2% MSG on taste intensity

The mean taste intensity scores of all 3 foods increased with higher concentrations of MSG (Figure 2a). The effect of concentration was significant for mashed potatoes and spinach [$F(4,236) > 9.7$, $p < 0.01$] and minced meat [$F(4,240) = 5.5$, $p < 0.01$]. The young participants had higher intensity ratings for the five concentrations compared to the elderly. Hence, the age effect for mashed potatoes, spinach [both $F(1,59) > 12$, $p < 0.01$] and for minced meat [$F(1,60) = 20.3$, $p < 0.01$] was significant. For mashed potatoes there was significant age x concentration interaction effect [$F(4,236) = 2.6$, $p < 0.05$], but the slopes of the curves were not different between the young and the elderly for spinach [$F(4,236) = 1.2$, $p = 0.3$] and minced meat [$F(4,240) = 0.9$, $p < 0.5$].

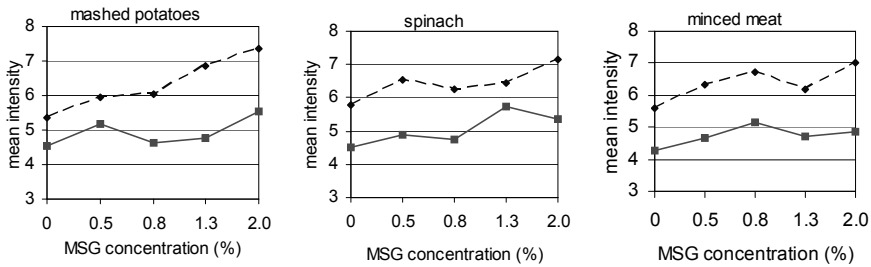


Figure 2a. Mean intensity ratings of mashed potatoes, spinach and minced meat as a function of MSG concentration in young (---◆---, n=29) and elderly (---■---, n=33, and n= 32 in spinach ratings) participants

Effect 0-2% MSG on pleasantness

The effect of concentration was significant for mashed potatoes and minced meat [both $F(4,240) > 3.1$, $p < 0.05$] but not for spinach $F(4,236) = 0.8$, $p = 0.5$. The pleasantness curve of mashed potatoes for the young participants peaked at 0.5% of MSG but the scores for the elderly people were stable from 0.5% MSG onwards (Figure 2b). The pleasantness of minced meat increased with increasing MSG concentration. There was no clear pleasantness optimum for spinach for both age groups.

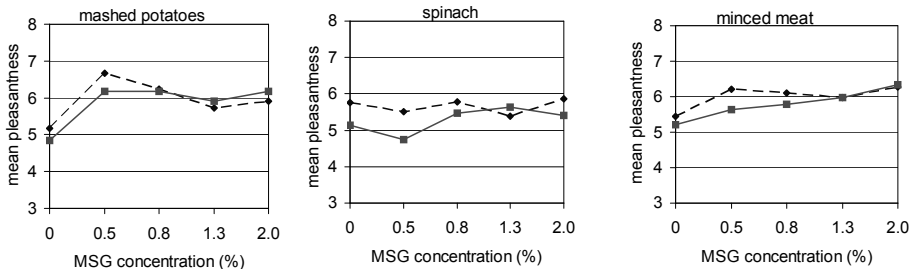


Figure 2b. Mean pleasantness ratings of mashed potatoes, spinach and minced meat as a function of MSG concentration in young (---◆---, n=29) and elderly (---■---, n=33, and n= 32 in spinach ratings) participants

The mean pleasantness responses over the five concentrations for each of the foods were not different between the age groups [mashed potatoes and minced meat $F(1,60) > 0.03$, $p > 0.6$]; spinach $F(1,59) = 1$, $p = 0.3$]. No interaction effect (age x concentration) was found for each of the foods, meaning that the slopes for the two

curves were not different [mashed potatoes and minced meat $F(4,240) > 0.4$, $p > 0.6$]; spinach $F(4, 236) = 0.7$, $p = 0.6$].

Effect of olfactory performance on pleasantness ratings

By means of the ETOC cut off values, we found little difference between the low and normal performing group. The averaged pleasantness responses over the concentrations in mashed potatoes were not different between the low and the normal performing group in the young plus elderly group [$F(1,60) = 0.1$, $p = 0.72$] and in the young group [$F(1,27) = 1.6$, $p = 0.2$]. Also, within the elderly group there was no sensory effect [$F(1,31) = 0.1$, $p = 0.8$].

Intake study

There was no difference in intake (kJ) (Table 2) between the minced meat with MSG versus without MSG ($p \geq 0.925$), spinach ($p \geq 0.685$), mashed potatoes ($p \geq 0.941$) and the total meal ($p \geq 0.896$).

Pearson's correlation coefficient (r) for the change in energy intake and the ETCO score (correct detection plus identification scores) was -0.24 ($p = 0.082$).

Table 2. Mean energy (kJ) (SD) intake of the hot meal components with and without MSG

Hot meal components	Energy (kJ)	
	+ MSG	- MSG
Minced meat	1113 (574)	1135 (602)
Spinach	83 (44)	85 (46)
Mashed potatoes	559 (315)	564 (322)
Total meal	1756 (881)	1774 (905)

DISCUSSION

This study showed that the consumption of mashed potatoes enhanced with an optimal preferred concentration of 0.5% MSG and spinach and ground beef with 2% MSG did not increase among institutionalized elderly.

Sensory study

Both the young and the elderly people preferred 0.5% MSG in mashed potatoes. For spinach no clear optimum of MSG was found within both age groups but for minced meat the pleasantness ratings given by the elderly people seemed to increase slightly upon higher MSG concentrations. The MSG range up to 2% is chosen partly due to the complex taste of spinach and minced meat. Although no clear optimum

was found in these foods, we believe our range was adequate and should not have been higher. Other studies find optimum preferred pleasantness ratings at MSG concentrations of 0.3%-0.9% (Rogers and Blundell 1990) or 0.6%-1.2% (Bellisle et al 1998) although one study used a range up to 6% or 8% (Yamaguchi and Takahashi 1984).

Our finding is in line with results by Mojet et al (2005) who did not find an optimum for pleasantness among young and elderly people with a range of 0.16% to 1% MSG in broth. Other studies are in contrast with our finding (Prescott 2004, Rogers and Blundell 1990, Yamaguchi and Takahashi 1984). Prescott and Young (2002) found that 0.8% MSG added to vegetable soup increased its palatability among young and elderly people. Furthermore, Bellisle et al (1989) found an optimum of 0.6% for beef jelly and spinach mouse when using a range varying from 0-1.2% MSG. The inconsistent results above could be due to a food related issue. As shown by Bellisle et al (1991 and 1996) optimum concentrations of MSG were more pronounced in starchy dishes than in vegetable dishes. Both spinach and minced meat have a complex taste and are both glutamic acid-rich foods. This may work against the palatability enhancing effect of added MSG.

The effect of the MSG concentration on perceived taste intensity was significant in all 3 foods. This is not entirely in line with results found by Mojet et al (2003). The intensity of the ascending concentrations of MSG dissolved in water was perceived as different but not when MSG was dissolved in a food product (bouillon). The effect of an increasing MSG concentration in a more neutral environment seems more pronounced than when dissolved in a product with a complex taste of itself. This is what our results show in the mashed potatoes (more neutral taste) versus spinach and minced meat.

We found no age related difference for a higher flavor preference while some studies report the opposite (De Graaf et al 1994 and 1996, Griep et al 2000, De Jong et al 1996, Kozłowska 2003, Murphy 1986, Murphy 1987). The age related difference might depend on the kind of flavor or taste. Perhaps for savory tastes like salt and umami, the difference in optimal preferred concentration between the age groups is less pronounced than for example sweet flavors (De Graaf et al 1996, Mojet et al 2005). In line with this, Zallen et al (1990) found no age related difference in optimal preferred salt concentrations and neither did Mojet et al (2005).

In agreement with Koskinen et al (2003b), Koskinen and Tuorila (2005), Kremer et al (2007) and Forde and Delahunty (2004) we found no association between an

impaired olfactory sensitivity and higher preferred flavor levels. In line with our results, Mojet et al (2005) did not find an effect of threshold sensitivity and perceived supra threshold intensity on optimal preferred concentrations of several flavors dissolved in water. The variation among elderly in their ability to perceive a flavor may add to the difficulty to relate the impaired sensory sensitivity to an increased liking of flavor-enhanced products.

Intake study

This study shows that the energy intake of the total hot meal or any of the separate foods with MSG did not increase compared to the same meal or components without MSG among institutionalized elderly people.

Because of practical reasons it was not possible to perform both the sensory study and the intake study in the same population of elderly people. Although both groups are institutionalized elderly people they are a heterogeneous group and may have a different sensory performance. Therefore, the optimal MSG concentration might have varied between the two groups.

Denture wear among 96% of our elderly population, could have contributed to our finding. Complete and/or partial denture wear has shown to affect food intake in several ways (Kapur and Soman 1964, Griep et al 1997, Wayler et al 1990). Because of ethical reasons no specific medication use could be asked for. Therefore, we are unaware if certain drugs were taken that affected olfaction and taste which could have interfered with our results. Instead we asked for specific diseases that are related to diminished olfaction, taste and/or intake such as diabetes, cancer and Parkinson disease. Subjects with any of these conditions were not included in this study.

The results of studies on adding extra flavor and/or MSG as a way to increase food intake are inconsistent. While some studies confirm a higher intake with higher sensory stimulation either with MSG and/or flavors (Mathey et al 2001), others do not (Griep et al 1997, Kozłowska et al 2003). Our results are in agreement with a recently performed long term trial (Essed et al 2007). In a study where flavor enhancers (primarily odors) were added to the diet of 39 institutionalized elderly during 3 weeks, the intake of only 3 out of 20 enhanced foods significantly increased (Schiffman and Warwick 1993). Although De Jong et al (1996) noted a higher preference for sucrose in breakfast items, no increase was found in the amount eaten because of the higher sweetness. Other studies report the opposite (Bellisle et al 1991 and 1996). Schiffman (1998) showed that an added combination of 0.3% to 1.0% MSG and flavor

to foods during a week improved energy intake by 10% or more in 40 out of 43 sick elderly. It is unclear which foods she used to enhance. Mathey et al (2001) added a mixture of MSG (0.3%) and flavors to the hot meal of elderly people and found an increased intake of the flavor-enhanced foods.

In line with a recently performed study (Essed et al 2007) we found that elderly people with a low olfactory performance have an increased intake of food when exposed to a flavor enhancement treatment compared to the elderly with a normal performance. This suggests that for the elderly with low olfactory scores, flavor amplification may hold potential to increase intake. However, not all elderly may benefit from flavor enhancement and this may be related to the finding that elderly are a heterogeneous group when it comes to olfactory functioning because the olfactory performance of some elderly people show overlap with the young adults (Thomas-Danguin et al 2003, Koskinen et al 2003a). Also, olfactory loss does not apply to all odors (Gilbert and Wysocki 1987).

In conclusion, we found that an optimal preferred MSG concentration of 0.5% MSG in mashed potatoes and 2% in spinach and minced meat does not necessarily guarantee a higher intake of these foods. Likely, factors such as denture wear, medicine use and the heterogeneity in olfactory functioning contribute as to why flavor enhancement can not be used as a one-size-fits-all approach.

Future research should focus more on the individual older adult and their status of chemosensory functioning to gain insight if and which compensatory strategy could be effectively used.

REFERENCES

- Bellisle F, Dalix AM, Chappuis AS, Rossi F, Fiquet P, Gaudin V, Assoun M, Slama G. Monosodium glutamate affects mealtime food selection in diabetic patients. *Appetite* 1996;26:267- 275
- Bellisle F, Monneuse MO, Chabert M, Larue-Achagiotis C, Lanteaume MT, Louis-Sylvestre J. Monosodium glutamate as a palatability enhancer in the European diet. *Physiol Behav* 1991;49:869-873
- Bellisle F, Tournier A, Louis-Sylvestre J. Monosodium glutamate and the acquisition of food preferences in a European context. *Food Qual Prefer* 1989;1;03-108
- Berkhout AM, Cools HJ, Mulder JD. Measurement or estimation of body length in older nursing home patients. *Tijdschrift voor Gerontologie en Geriatrie* 1989;20:211-214
- De Graaf C, Polet P, van Staveren WA. Sensory perception and pleasantness of food flavors in elderly subjects. *J Gerontol A Biol Sci Med Sci* 1994;49:93-99
- De Graaf C, van Staveren W, Burema J. Psychophysical and psychohedonic functions of four common food flavors in elderly subjects. *Chem Senses* 1996;21:293-302
- De Jong N, De Graaf C, Van Staveren WA. Effect of sucrose in breakfast items on pleasantness and food intake in the elderly. *Physiol Behav* 1996;60:1453-1462
- Essed NH, van Staveren WA, Kok FJ, De Graaf C. No effect of 16 weeks flavor enhancement on dietary intake and nutritional status of nursing home elderly. *Appetite* 2007;48:29-36
- Forde CG, Delahunty CM. Understanding the role cross-modal sensory interactions play in food acceptability in younger and older consumers. *Food Qual Prefer* 2004;15:715-727
- Gilbert AN, Wysocki CJ. National Geographic smell survey: The results. *Natl Geogr Mag* 1987;172:514-525
- Griep MI, Mets TF, Massart DL. Different effects of flavour amplification of nutrient dense foods on preference and consumption in young and elderly subjects. *Food Qual Prefer* 1997;8:151-156
- Griep MI, Mets TF, Vogelaere P, Collys K, Laska M, Massart DL. Odor perception in relation to age, general health, nutritional status, and dental status. *Arch Gerontol Geriatr* 1997;25:263-275
- Griep MI, MetsTF, Massart DL. Effects of flavor amplification of Quorn and yoghurt on food preference and consumption in relation to age, BMI and odour perception. *Br J Nutr* 2000;83:105-113
- Guigoz Y, Vellas B, Garry PJ. Assessing the nutritional status of the elderly: the Mini Nutritional Assessment as part of the geriatric evaluation. *Nutr Rev* 1996;54:S59-65
- Henderson HHF, Toors H, Ebbelink-Bosch IJ, Rijks SE. *Het nieuwe kookboek*. 1999. Kosmos Uitgevers BV, Utrecht, Nederland
- Kapur KK, Soman SD. Masticatory performance and efficiency in dental wearers. *J Prosthet Dent* 1964;14:687-694
- Koskinen S, Kalviainen N, Tuorila H. Perception of chemosensory stimuli and related responses to flavored yogurts in the young and elderly. *Food Qual Prefer* 2003a;14:623-635
- Koskinen S, Kalviainen N, Tuorila H. Flavor enhancement as a tool for increasing pleasantness and intake of a snack product among the elderly. *Appetite* 2003b;41:87-96

Chapter 5

- Koskinen S, Tuorila H. Performance on an odor detection and identification test as a predictor of ortho- and retronasal odor intensity ratings in the young and elderly. *Food Qual Prefer* 2005;16:383-392
- Kozłowska K, Jeruszka M, Matuszewska I, Roszkowski W, Barylko-Pikielna N, Brzozowska A. Hedonic tests in different locations as predictors of apple juice consumption at home in elderly and young subjects. *Food Qual Prefer* 2003;14:653-661
- Kremer S, Bult JHF, Mojet J, Kroeze J. Compensation for age-associated chemosensory losses and its effect on the pleasantness of a custard dessert and a tomato drink. *Appetite* 2007;48:96-103
- Mathey MAM, Siebelink E, De Graaf C, van Staveren WA. Flavor enhancement of food improves dietary intake and nutritional status of elderly nursing home residents. *J Gerontol A Biol Sci Med Sci* 2001;56:M200-M205
- Mojet J, Christ-Hazelhof E, Heidema J. Taste perception with age: pleasantness and its relationships with threshold sensitivity and supra-threshold intensity of five taste qualities. *Food Qual Prefer* 2005;16:413-423
- Mojet J, Heidema J, Christ-Hazelhof E. Taste perception with age: generic or specific losses in supra-threshold intensities of five taste qualities? *Chem Senses* 2003;28:397-413
- Murphy C. Flavor preference for monosodium glutamate and casein hydrolysate in young and elderly persons. 1987. *Umami: A basic taste*, pp139-151. Marcel Dekker, New York, USA
- Murphy C, Withee J. Age-related differences in the pleasantness of chemosensory stimuli. *Psychol Aging* 1986;1:312-318
- Nevo. Stichting Nederlands voedingsstoffenbestand. Dutch Nutrient Database 1997, The Hague, The Netherlands: Voorlichtingsbureau voor de voeding
- Prescott J. Effects of added glutamate on liking for novel food flavors. *Appetite* 2004;42:143-150
- Prescott J, Young A. Does information about MSG (monosodium glutamate) content influence consumer ratings of soups with and without added MSG? *Appetite* 2002;39:25-33
- Rogers PJ, Blundell JE. Umami and appetite: effects of monosodium glutamate on hunger and food intake in human subjects. *Physiol Behav* 1990;48:801-804
- Roininen K, Lähteenmäki L, Tuorila H. Effect of umami taste on pleasantness of low-salt soups during repeated testing. *Physiol Behav* 1996;60:953-958
- Rolls BJ. Appetite, hunger, and satiety in the elderly. *Crit Rev Food Sci Nutr* 1993;33:39-44
- Rolls BJ. Do chemosensory changes influence food intake in the elderly? *Physiol and Behav* 1999;66:193-197
- Schiffman SS. Perception of taste and smell in elderly persons. *Crit Rev Food Sci and Nutr* 1993;33:17-26
- Schiffman SS. Sensory enhancement of foods for the elderly with monosodium glutamate and flavors. *Food Rev Int* 1998;14:321-333
- Schiffman SS, Miletic IDJ. Effect of taste and smell on secretion rate of salivary IgA in elderly and young persons. *J Nutr Health Aging* 1999;3:158-164

Optimal preferred MSG concentration in potatoes, spinach and beef

Schiffman SS, Sattely-Miller EA, Zimmerman IA, Graham BG, Erickson RP. Taste perception of monosodium glutamate in foods in young and elderly subjects. *Physiol Behav* 1994;56:265-275

Schiffman SS, Warwick ZS. Flavor enhancement of foods for the elderly can reverse anorexia. *Neurobiol Aging* 1988;9:24-26

Schiffman SS, Warwick ZS. Effect of flavor enhancement of foods for the elderly on nutritional status: Food intake, biochemical indices, and anthropometric measures. *Physiol Behav* 1993;53:395-402

Ship JA, Weiffenbach JM. Age, gender, medical treatment, and medication effects on smell identification. *J Gerontol* 1993;48:M26-32

Stevens JC, Bartoshuk LM, Cain WS. Chemical senses and aging: taste versus smell. *Chem Senses* 1984;9:167-179

Stevens JC, Cruz LA, Hoffman JM, Patterson MQ. Taste sensitivity and aging, high incidence of decline revealed by repeated threshold measures. *Chem Senses* 1995;20:451-459

Thomas-Danguin T, Rouby C, Sicard G, Vigouroux M, Farget V, Johanson A, Bengtzon A, Hall G, Ormel W, De Graaf C, Rousseau F, Dumont JP. Development of the ETOC: a European test of olfactory capabilities. *Rhinology* 2003;41:142-151

Wayler AH, Perlmutter LC, Cardello AV, Jones JA, Chauncey HH. Effects of age and removable artificial dentition on taste. *Spec Care Dentist* 1990;10:107-113

Yamaguchi S, Takahashi C. Hedonic functions of monosodium glutamate and four basic taste substances used at various concentration levels in single and complex systems. *Agric Biol Chem* 1984;48:1077-1081

Zallen EM, Hooks LB, O'Brien K. Salt taste preferences and perceptions of elderly and young adults. *J Am Diet Assoc* 1990;90:947-950

Rouby, Note1. Catherine Rouby, Neurosciences et Systemes Sensoriels, Universite Claude Bernard Lyon 1, France. E-mail: rouby@olfac.univ-lyon1.fr

6

General discussion

Chapter 6

The aim of this present thesis was to investigate the effect of flavor enhancement (by adding a taste compound and/or an odor to a food in order to enhance or intensify its own flavor) on liking and food intake in elderly people and the relationship between an altered taste and/or smell performance and liking of flavor-enhanced foods. Up until 2003 there were studies, which showed that flavor enhancement increased the consumption of foods. However, as explained in Chapter 1 these results were inconsistent (Bellisle et al 1996, Bellisle et al 1991, Mathey et al 2001, Schiffman 1998). This led to several research questions (see Table 3 in Chapter 1 Introduction) and thus studies that are addressed in the previous chapters. In this chapter we summarize our main findings, reflect on our hypothesis and present a rationale for a future strategy.

1. MAIN FINDINGS

Our findings and characteristics of the studies are summarized in Table 1. The results clearly demonstrate that we cannot confirm our hypothesis at the start of this research that flavor enhancement of foods will increase liking and subsequently intake among elderly people. Also, no relationship was established between an altered taste and/or smell performance and liking of flavor-enhanced foods (Figure 1).

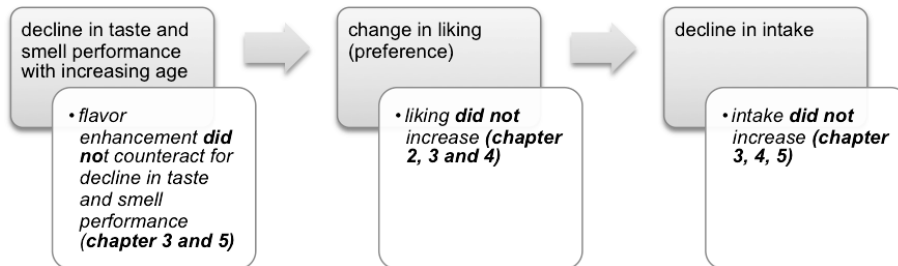


Figure 1. Hypothesized model of how a decline in taste and smell performance may influence food intake among elderly people (grey boxes) and the obtained main results of the hypothesized solution (italic) to increase liking and/or intake with flavor enhancement.

Table 1. Summary of the characteristics of the study and findings per chapter

Chapter	Aim	Design/method	Population	Main finding
2	The effect of repeated exposure to fruit drinks with different sweet intensities on intake, pleasantness and boredom	Randomized within subject cross over trial with 3 intervention periods of 12 days	Young (n=32) and Elderly (n=36) women	In the elderly mean pleasantness and boredom remained stable and intake increased
3	The effect on intake and liking of soup enhanced with MSG and celery powder vs non-enhanced soup among elderly with impaired taste and/or smell performance	Single blind randomized within subject cross over trial with 4 test days -Olfactory test -Gustatory test	Elderly (N=120) over 4 groups each with certain taste and/or smell performance	No increased intake and liking of the flavor-enhanced soup among elderly with impaired taste and/or smell performance
4	Long-term effect of flavor enhancement (MSG and/or flavors) on dietary intake, pleasantness and nutritional status	Single blind randomized parallel trial (16 weeks) -Olfactory test	4 groups of elderly 1) control (n=23) 2) MSG (n=19) 3) flavor (n=19) 4) MSG + flavor (n=22)	No increased energy intake, pleasantness and body weight in any of the groups
5	Two-fold study: 1a) Determine optimal preferred MSG concentration in mashed potatoes, ground beef and spinach 1b) Is there a relationship between olfactory performance and pleasantness ratings? 2) The effect of the obtained optimal MSG concentrations on intake	1) MSG range of 0,0.5,0.8,1.3, 2 g/100g in foods in randomized order 2) Single blind randomized within subject cross over trial with 4 test days within 4 weeks -Olfactory test	1) Young (n=29) and elderly (n=33) 2) Elderly (n=53)	1a+2) In the elderly, no increased intake after consumption of foods with an optimal MSG concentration 1b) In the young and elderly, no relationship between an impaired olfactory performance and higher preferred flavor level

2. REFLECTION ON OUR HYPOTHESIS

Results by others and us did not support the hypothesized solution that flavor enhancement may improve liking (Kremer et al 2007a, Mojet et al 2005) and/or intake (Essed et al 2009a, Essed et al 2009b, Essed et al 2007). Perhaps the associations are more complex and not as straightforward as previously assumed. To pursue this, we reflect on the relations between the items in the hypothesized model (Figure 1).

The relationship between a declined taste and smell performance and liking

Several studies show that a decline in taste and smell performance with aging causes a change in food perception among elderly (de Graaf et al 1994, Kremer et al 2007b, Mojet et al 2003). However, whether this leads to a change in liking is not confirmed (Essed et al 2009a, Essed et al 2009b, Forde and Delahunty 2004, Koskinen et al 2003b, Koskinen and Tuorila 2005). One explanation could be that liking among elderly people remains fairly stable. According to recent work, the elderly show no decline in food liking regardless of their diminished taste and smell performance (Kremer et al 2007a, Kremer et al 2007b). The authors concluded that a decreased taste and olfactory acuity does not cause a reduced food liking and intake. The gradual adjustment to the reduced taste and smell performance could be a reason why liking does not become affected (Rolls 1993) and/or the fact that perception and liking are processed in different areas of the brain (de Araujo et al 2003, Sowards 2004).

Thus, the relationship between a declined taste and smell performance and a higher liking of a flavor-enhanced product has been explored in several studies but has not been established. This could be due to the finding that liking remains fairly stable. So far we have to conclude that this relationship remains uncertain.

The relationship between liking and intake

At first, this association seems transparent since liking highly correlates with intake under controlled laboratory conditions (Zandstra et al 1999). However, in a more naturalistic setting it becomes apparent that environmental factors (where, how, when and with whom) turn out to be important (de Graaf et al 2005).

While liking has been recognized to have a strong impact on intake in children (Birch 1999), within elderly it no longer seems the sole factor that influences intake. A study by de Castro (2002) showed that elderly in a realistic environment are equally receptive as younger adults to factors such as social facilitation, cognitive restraint, location and palatability that influence intake. However, this was different for hunger. Compared to the younger people, hunger seemed to have an impaired ability to

affect intake in the elderly. In addition, the association between self-rated hunger and the amount ingested was weaker for the elderly. It seems that upon aging, the influence of environmental and social factors become more determinative for food intake than internal factors such as satiety, hunger and thirst (De Castro 1993).

One factor of interest noted by de Castro (2002) is that palatability, despite taste and smell losses is just as valuable for the elderly to promote intake as in the young adults. Accordingly, the author concluded that offering elderly highly palatable foods might be important to counteract for the deficient intake. This immediately raises the question as to why flavor enhancement in our studies, which aimed to increase the palatability of the food did not stimulate intake. Our results show that flavor enhancement did not increase pleasantness or liking. We have discussed several reasons in the previous chapters -varying from a low dose of MSG, a population that is too old and therefore less sensitive to changes in flavor concentration, medicine use, to denture wear - that undoubtedly all add to our results and as last, perhaps we did not offer a highly enough palatable food that can be perceived as such.

With in mind that elderly are less sensitive to a repeated monotonous intake meaning that pleasantness does not decrease after consumption, offering highly palatable foods would seem sensible to stimulate intake in elderly people. However, since each person perceives palatability differently, the desired level should be determined individually.

Thus, on the one hand liking does not seem to be influenced by an alteration in taste and smell performance but on the other hand, palatability is still important for food intake in the elderly. Based on what has been described above, we can conclude that for a future strategy targeted to stimulate food intake in the elderly, social, environmental and psychological factors such as palatability need to be taken into consideration and should be tailored to the requirements of the individual, especially in the case of palatability.

3. HOW DO WE PROCEED FROM HERE?

After 3 studies in which we did not succeed to find an effect of flavor enhancement on liking and/or intake we asked ourselves several questions. Firstly, is a standardized flavor enhancement treatment the right approach to increase liking and/or intake? It did not prove to be a one-size-fits-all solution and perhaps this may be partly explained by the fact that the elderly are a heterogeneous group when it comes to health issues but also chemosensory performance.

Secondly, how or what should we have done differently? To address this, we wanted to take a closer look at the elderly to find out how this group can be differentiated because of their heterogeneity. Can they be differentiated based on the changes in chemosensory performance and what are the causes? We performed an in-depth search for the factors that alter taste and smell performance upon aging to gain a better understanding of how and to what extent these factors influence the performance. In addition, we speculated that perhaps in some cases, the taste and/or smell performance can be improved by treating the cause and flavor enhancement would not be needed to treat the symptom.

Thirdly, if there is enough evidence to differentiate, how reliable and feasible are the tests currently available to measure the taste and smell performance needed for the differentiation?

Therefore, before we reject our theory that a standardized flavor enhancement in contrast to for instance a personal adapted enhancement, is the right approach to increase liking/and or intake, as comprised in the hypothesized model, we present:

3.1 A review of the current knowledge on the factors upon aging that affect taste and smell performance in the elderly population

3.2 A review of the methodology to measure the taste and smell performance

3.3 Suggestions for further strategies to help elderly people with various degrees of taste and smell decline.

3.1 FACTORS THAT AFFECT THE TASTE AND SMELL PERFORMANCE UPON AGING

The taste system: peripheral to central changes

Peripheral to central changes include those in the oral cavity (e.g. taste buds amounts, saliva or oral appliances) to the neuronal fibers that connect to the brain. There is an extensive amount of research that connects alterations in these areas with aging to a diminished (hypogeusia), altered (dysgeusia) or lost taste perception (ageusia) (Table 2a). However, it is difficult to distinguish between the taste and smell dysfunctions that are directly related to aging and those resulting from diseases and medication that frequently occur in elderly people.

It must be noted that as far as the overall chemosensory perception of a stimulus concerns; individuals are not capable to discriminate between the input of taste and smell. Therefore, chances are that many taste complaints are actually olfactory disorders because of the overlapping and redundant nature of taste innervation.

Taste buds

Taste buds are mainly located on the tongue, soft palate, pharynx, larynx, epiglottis but also on the uvula and the first one-third of the esophagus (Scott 1992). Which age related changes concerning the taste buds affect taste perception? Discussed are the number of taste buds, the taste receptor cell membrane and receptor cell turnover.

Age related changes in taste bud numbers have been examined in humans and animals. Early anatomical studies find a decline in human circumvallate papillae with aging but autopsy material of ill individuals was used and no statistical data analysis was performed (Arey et al 1935). Later studies report minimal age related losses of fungiform papillae in humans (Arvidson 1979, Miller 1988, Miller 1989) but the tongues of only 22 and 18 subjects respectively were studied. Mistretta and Baum (1984) found similar results for fungiform papillae and circumvallate papillae in rats. A decade later, Shimizu (1997) analyzed materials from 241 human cadavers without pathological changes and suggested that the taste bud density in the circumvallate papillae and the taste receptor cell density decreased with age. However, there was no difference in taste bud number between the old group (>76 yrs) and the 2 younger groups (0-15 yrs and 16-35 yrs), only between the old and middle (36-55 yrs) group. Furthermore, the taste receptor cells did not decrease in number or in their transcriptional activity but did show an increase in size with age, which also affects

the taste bud size. The latter may explain the decrease in taste bud density and taste receptor cell density.

Comparable to the results of the previous study, Segovia et al (2002) found that children (8-9 yrs) had a higher papillae density than adults (18-30 yrs). Both groups had similar amount of taste pores per papillae but the children had smaller taste pore diameters and thus smaller size fungiform papillae. Kobayashi et al (2001) found entirely flat areas with no papillae on the tongue. Related to the lingual flat areas regional losses in taste perception on the tongue of elderly are reported (Bartoshuk et al 1987) such as for NaCl (Matsuda and Doty 1995). Further taste sensitivity decline have also been found for some bitter components (Cowart et al 1994).

A higher taste bud density seems be associated with greater taste sensitivity. Smith (1971) reported in an early study that the intensity of taste perception at constant stimulus concentration and flow rates was proportional to the number of fungiform papillae located in a stimulated region. This was later confirmed by Miller and Reedy (1990) who found that subjects with a higher taste bud density report tastants as NaCl, PROP (6-n-propylthiouracil) and sucrose as more intense compared to subjects with fewer taste buds. In addition, Zhang et al (2009) found an inverse correlation between the fungiform papillae density and the sucrose detection threshold in subjects aged 18-23. Apparently there is a high variation in taste bud density within a certain age group of humans (Arvidson 1979) and this is associated with differences in their taste intensity ratings (Miller and Reedy 1990). They also found that the taste bud density of some older subjects equals the density of youngest subjects. Perhaps the above results are part of the reason why the taste perception of some older people is similar to that of young people. There is no clear explanation why the prevalence of taste buds differs among subjects within an age group. Genetics, aging, medication, tobacco use and pathology are presented to be possible causes (Miller and Reedy 1990).

In contrast, Mavi and Ceyhan (1999) proposed that the loss of taste perception with normal aging is barely related to the diminished taste bud density. Some taste losses may also be due to the changes in cell membranes that involve an altered functioning of ion channels and receptors and/or alterations in neurotransmitter level (Schiffman 2007). The age-associated decline in taste sensitivity might also be due to a delayed turnover of the taste cell receptors as seen in aging mice (Fukunaga 2005). Normally the cells are renewed about every 10-10.5 days but the delayer may cause a drop in taste cell response. To our current knowledge, this is not yet examined in humans.

It remains inconclusive from the literature whether or not there is a decline in taste bud (fungiform and circumvallate) density and taste bud number with aging. It is also unclear if there is in fact an increase in size of the taste receptor cell with aging and if so, how does that affect the taste bud number, taste bud density and taste intensity? More quantitative studies across different age groups and genders are needed to establish this. Nevertheless, several studies have confirmed a high variation in taste bud density within different age groups. This seems to account for the wide variation of taste thresholds among people within a similar age group. Possibly, a delayed cell turnover may also add to the decline in taste sensitivity with age. But so far, there is limited evidence that this occurs in humans.

Saliva

Saliva secretion results from three major paired glands (parotid, submandibular and sublingual) and numerous minor glands. Saliva dissolves the stimulus, it transports the stimulus to and from the receptors and regulates the concentration of the stimulus.

With normal aging, acini (saliva producing cells) in the salivary glands are replaced by fat and fibrotic tissue and oncocytes (Waterhouse et al 1973) but the number of ducts remains unchanged (Scott 1987). Regarding the effect of age on salivary flow, a distinction can be made between secretion in stimulated and unstimulated conditions. Several studies report that there is no age related change in the secretion of parotid gland saliva in healthy unmedicated people in a stimulated condition (Ben-Aryeh et al 1986, Vissink et al 1996). In unstimulated resting conditions the results of studies seem to contradict. Some find a significant reduction of salivary secretion in elderly people mostly from submandibular gland (Ben-Aryeh et al 1984, Nagler and Hershkovich 2005) while others do not observe a decrease in saliva flow rate of the submandibular gland with age in unstimulated and stimulated conditions (Ship et al 1995, Tylenda et al 1988). These differences may partly be explained by the different saliva sample-collecting methods and the conditions. Also, perhaps an age related decline in saliva flow is more related to a particular gland type. Despite the age associated reduction in acinar cells, there seems to be consensus that the major glands fluid secretion is not significantly reduced with age in healthy unmedicated people (Ghezzi et al 2000, Ship and Baum 1990, Ship et al 1995). Ghezzi and Ship (2003) hypothesized that this can be explained by the existence of a secretory reserve in the salivary glands that accounts for the loss of acinar cells in normal aging to preserve function. In addition, the organic composition of excreted saliva in the absence of serious medical problems and medications also appears to be age stable (Wu et al 1993). Nevertheless, many elderly people actually experience

elevated detection threshold for specific tastants due to dry mouth because of insufficient secretions (xerostomia) (Weiffenbach et al 1986). In these cases, the taste disturbances due to salivary dysfunction are often associated with head and neck radiotherapy, Sjogren's syndrome, disease, medications or idiopathic and not because of age per se (Nagler 2004).

Thus, the histological alterations with aging of the saliva glands do not necessarily lead to a reduction of the capacity to produce saliva. Since the impact of aging on the flow rate and composition of saliva of the major glands appears to be minimal in healthy aging, this suggests that taste problems in elderly people due to an insufficient saliva production are more likely because of diseases and their treatments than to aging itself.

Oral diseases and treatments

The oral causes of taste dysfunction in elderly people include dental-alveolar infections, periodontal diseases, soft tissue disorders (e.g. candidosis, herpes zoster and cancer) burning mouth syndrome, but also treatments such as head and neck radiotherapy, removable prosthodontic appliances and mouth rinses (Ship 1999).

Dental alveolar infections, which can originate from untreated dental caries and mucosal infections can cause dysgeusia by producing noxious bacterial byproducts. Oral candidosis, a fungal infection, also affects taste sensation. It is characterized by white patches on the tongue and can be caused secondary to certain medication use, salivary dysfunction or lack of dental hygiene. Tongue brushing of lightly coated tongues of elderly people has shown to improve taste sensitivity (Ohno et al 2003).

Burning mouth syndrome (BMS) is described as chronic burning and painful sensations in the mouth in the absence of having any visible clinical signs (Patton et al 2007). It occurs in both genders but it mainly affects women after menopause and the prevalence in this group is about 12% (Bergdahl and Bergdahl 1999). Patients often report having an altered taste (dysgeusia) with salt perception being most affected (70%). It is considered to have no specific cause but several physical factors (e.g. peripheral nerve damage, decreased salivary flow, oral candidosis, endocrine factors such as diabetes and menopause, nutritional deficiencies, neurological diseases) and psychiatric conditions (e.g. depression, anxiety, phobia) (Cerchiari et al 2006, Grushka et al 2002) have been classified as etiological factors. Burning mouth is relatively highly prevalent among women over 60 yrs of age, but so far treatment of some etiologic factors has proved ineffective except for

electroconvulsive therapy (ECT) performed on one person (Suda et al 2008). Thus, treatment of this syndrome deserves more attention.

It is well known that radiation or chemotherapy to treat head and neck cancer affects cell proliferation and can decrease the rate of cell turnover and salivary flow. This subsequently may affect taste perception. Other mechanisms include alteration of the normal oral flora and drug secretion in oral fluid. The reported taste alterations include dysgeusia and ageusia (Ship 1999).

With aging, the prevalence and extent of tooth loss increases (Nalcaci et al 2007) and removable dentures are used to replace the missing teeth. Denture wear has shown to interfere with taste perception (Chauncey et al 1984, Nalcaci and Baran 2008). For example, maxillary dentures can alter taste perception by covering the palate including some of the taste buds (Henkin and Christiansen 1967, Posner et al 1994). More specifically, sodium chloride recognition thresholds tend to be higher for people older than 65 yrs wearing removable partial and complete dentures while dentition status had no effect on sucrose thresholds (Wayler et al 1990). This means that denture wearers need a higher concentration of salt to identify its taste. The intensity perception of sodium chloride is also reduced (temporarily) by the use of oral mouth rinses containing 0.2% chlorhexidine (Breslin and Tharp 2001, Helms et al 1995).

In summary, among the many oral conditions, oral infections are common causes of altered taste perception. Burning mouth syndrome seems to have multifactorial causes but these are poorly understood. So far, treatments of these causes are inadequate and need to be further explored. Other oral sources of altered taste perception are more related to systemic conditions and their treatments such as radiation, chemotherapy and denture wear rather than to aging

Damage to the neural pathways

Gustatory disorders can result from damage at basically any point of the neural taste pathway. From the cranial nerves VII, IX and X that transmit the taste information from the taste buds cell in the oral cavity to the brain via the solitary tract nucleus. The damage may lead to partial loss (hypogeusia), complete loss (ageusia) or a sensation of altered taste (dysgeusia).

Two nerves, the chorda tympani (CT) (branch of nerve VII) and the glossopharyngeal (cranial nerve IX) are important for taste perception. The CT innervates the fungiform papillae as well as some foliate papillae on the anterior two-thirds of tongue and the

glossopharyngeal (nerve IX) innervates most of the foliate and all of the circumvallate papillae in the posterior tongue. The CT can be damaged pathologically (e.g., ear infection, upper respiratory infection, Bell's palsy and herpes zoster oticus) and surgically (stapedectomy, anesthesia, dental procedures) (Weiffenbach and Bartoshuk 1992). The amount of manipulation of the CT nerve is determinative of how much taste perception is affected. If the CT is stretched or crushed, taste perception is affected and the patient may experience taste phantoms (metallic, occasionally salty or bitter) (Bull 1965) but this normally recovers (Barry and Frank 1992). More than half of the patients that underwent surgery with sectioning of the CT reported taste disorders (Sakagami 2005). After two years, EGM (electrogustometry for evaluation of taste sensitivity) threshold did not recover but symptoms of taste disorders ceased. After middle ear surgery, major manipulation of the CT decreased taste function whereas patients with a minor manipulation reported no taste changes (Mueller et al 2008). Apart from the amount of manipulation, age also seems to be an important factor for taste function improvement as the recovery rate of EGM threshold was greater in young people (<20 yrs) than in the older group (41-60 yrs) (Sone et al 2001). Interestingly, while a single nerve may be damaged or cut, the CT for example, the perceived taste intensity is hardly affected. This can be explained due to release of inhibition on taste from the other cranial nerve, the glossopharyngeal, to preserve whole mouth taste perception (Catalanotto et al 1993).

In case of dental deafferentation, results show that the higher the number of deafferented teeth, the higher the EGM thresholds (Boucher et al 2006). Especially in subjects with more than 7 deafferented teeth compared to those with fewer deafferented teeth, regardless of age. This suggests that dental deafferentation is likely to cause taste impairment rather than age.

More specific to aging is a decrease in size of the human tractus solitarius found by Yamamoto et al (2005) in males with the use of an image-analyzer system. According to this study, a certain level of taste function loss could be associated to the aging process in males.

Concluding, both the chorda tympani (CT) and the glossopharyngeal are essential nerves for taste perception. Damage to the CT can be pathologically and/or surgically and the taste dysfunction depends on the severity of the damage. A phantom taste may be experienced after crushing or stretching the CT and altered taste sensitivity after sectioning of the CT or dental deafferentation but perceived taste intensity stays intact. This is because the release of inhibition from the other nerve serves to keep the consistency of perceived taste intensity.

Medical conditions that affect taste perception

The medical conditions that can affect taste perception in elderly people are numerous and can be subdivided in nervous, nutritional, endocrine, local, viral and bacterial infections (Schiffman and Zervakis 2002). Here we describe conditions specific to the older population like diabetes mellitus, Alzheimer disease (AD) and Parkinson's disease (PD).

It seems that diabetes patients with neuropathy often report symptoms such as dry mouth and decreased salivary flow and the latter can have an impact on the prevalence of dental caries (Moore et al 2001). In a case control study, the majority of diabetes mellitus type 1 patients (insulin dependent) had decreased taste sensitivity for all four basic tastes measured with electrogustometry and chemical gustometry. The taste disorder was not only related to the diabetes status but also to complications of the disease such as peripheral neuropathy and microalbuminuria, age and to the duration of diabetes (Le Floch et al 2008, Le Floch et al 1989, Le Floch et al 1990).

With Alzheimer there is a reduced innervation of the taste buds, which may to a degree cause the taste sensitivity to decline (Yamagishi et al 1995). Schiffman et al (1990) found higher detection thresholds for glutamic acid but not for quinine HCL in people with AD and in demented people without AD. The results imply that taste loss in demented people depends on the chemical structure of the tastant. Regarding Parkinsons disease (PD), Sienkiewicz-Jarosz (2005) performed a case control study and found that PD patients did not experience a difference in intensity, pleasantness and identification of the four basic tastes excluding the lowest quinine concentration. That was the only stimulus that was rated more intense compared to the control group by means of electrogustometry.

People with bacterial and viral infections can experience taste dysfunctions due to interferons (IFNs) produced during infection that directly affect the taste bud cells. This has been confirmed in mice and rats (Wang et al 2007) but results are not shown in humans so far. It has been suggested that the elevated levels of IFNs promote apoptosis of taste bud cells leading to a net loss of functional taste receptor cells, which may cause taste dysfunctions.

In summary, type 1 diabetes mellitus, Alzheimer disease and Parkinson's are common conditions among elderly people where taste perception could be affected. In diabetes mellitus type 1, taste impairment is a gradually worsening complication and also related to the complications of the disease. In Alzheimer, the declined taste

sensitivity may depend on the chemical structure of the stimuli. People with Parkinson's do not experience major alterations in taste intensity and identification but in some cases they may show increased taste sensitivity.

Critical illnesses

Cancer is one of the many critical illnesses that may occur in elderly people that can affect taste functioning. Taste disorders appear in both treated (chemotherapy and radiation) (Fetting et al 1995) and untreated people with cancer (Ovesen et al 1991). Taste can be affected due to metabolic changes (nutritional deficiency) caused by the tumor and damage to the sensory receptors by radiation. Furthermore, chemotherapy drugs can interfere with the turnover and replication of the taste receptor cells causing the turnover to decrease (Schiffman and Zervakis 2002).

There are numerous studies that describe the chemosensory change that occurs in a specific type of cancer. In general, the data shows that cancer and the treatments elevate detection and recognition thresholds for the four tastants and that people experience a lesser ability to discriminate and identify tastants (Schiffman and Graham 2000). Most studies, although different between the type of cancer and the kind of treatment, report higher thresholds for sweet, salt and sour while for bitter some report elevated and some show decreased thresholds. Self-reported complaints by the cancer patients usually involve an unpleasant taste such as bitter or metallic taste (Rhodes et al 1994) which can be caused by the chemotherapy drugs. Patients with head and neck cancer receiving radiotherapy, reported elevated detection and recognition thresholds for bitter and salt (Mossman and Henkin 1978). DeWys and Walters (1975) found that half of their research population with various types of cancer had an elevated taste threshold for sweet and some had a lowered threshold for bitter. People with breast and colon cancer, before receiving treatment, experienced an increased salt recognition threshold. Carson and Gormican (1977) noted a correlation between the increased salt threshold and the tumour extent. Gorshein (1977) observed that in patients that underwent hypophysectomy the taste abnormalities returned to normal after surgery. This suggests that the extent of the tumour also affects the taste alterations.

There are many factors to consider that could affect the changes in taste beside the extent of the tumor and chemotherapy. Factors such as zinc status (Henkin 1994), the length of the treatment, type of chemotherapy, type of sensory measurement and the site of the tongue for measurement, smoking and age. It is therefore difficult to make a distinction between how much of the taste alteration results from the tumor itself or from the treatment.

Lastly, gustatory dysfunctions have been reported in patients following stroke (Heckmann et al 2005). The symptoms included hypogeusia (diminished taste) and dysgeusia (distorted taste). It seems that gustatory loss correlates positively with male gender, a high functional effect of the stroke as measured by the National Institutes of Health Stroke Scale (NIHSS), having swallowing disorder and partial anterior circulation syndrome mostly in the frontal lobe.

Medication that affect taste perception

There are numerous drugs that are likely to affect the taste perception. Elderly people in particular are at risk for the drug induced taste disorders because of the many medications they take for the chronic diseases they may experience.

Medications can induce taste dysfunction at several levels. They can prevent access of the stimuli to the receptors by closing off taste pores; change the chemical environment of the receptors by altering the composition of the saliva; interact with the receptive process at the level of the receptor; interfere with the spread of neural impulses within the cellular membranes of the neurons; change neurotransmitter function and alter processes within the neural network in the brain regions (Doty and Bromley 2004). Sometimes, the taste of the drug itself may interact with the receptor and cause the sensory complaint. This may occur when the drug is ingested orally, excreted in the saliva or via the tongue blood vessels and interacts with the receptors.

Some of the major classes of drugs that interfere with taste are antimicrobials, antihypertensives, antihyperlipidemics, antiproliferatives and corticosteroids, antirheumatics and anti-inflammatory agents, hyper- and hypoglycemic drugs, drugs to treat Parkinson's, antidepressants. Antimicrobials can affect taste by having a taste of their own and by changing the taste of other tastants when applied on the tongue. Most are perceived as bitter, sour and/or metallic and some alter the tastes of sodium, potassium, and/or calcium salt and citric acid. Within the class of antihypertensives, angiotensin –converting enzyme inhibitors and angiotensin II antagonists can cause taste disorders such as ageusia (loss of taste), metallic taste, sweet taste and dysgeusia (taste distortion). Several antihyperlipidemics have been reported to have side effects such as ageusia, dysgeusia and parosmia (Schiffman and Zervakis 2002). Some antiproliferatives such as chemotherapeutic agents can affect taste by disturbing the renewal of taste receptor cells since these proliferate every 10-10.5 days (Berteretche et al 2004). The taste alterations include metallic taste and bitter taste. Immunosuppressants such as corticosteroids target the immune system and can cause candidal overgrowth. This can add to the prevalence

of dysgeusia (Murray and Solish 2003). Other drugs that affect taste are the antirheumatics and anti-inflammatory agents. Complaints include dysgeusia, metallic taste, hypogeusia, ageusia and bitter taste. Many taste complaints because of hyper- and hypoglycemic drugs include ageusia, an altered taste and bitter taste, depending on the specific drug. Most drugs to treat Parkinson's disease can cause hypogeusia and ageusia and some can cause a bitter and metallic taste. Another class of drugs to affect taste includes antidepressants. Apparently the drugs have a taste of their own which may be bitter and they can change the intensity of other tastes such as salt and sugar (Schiffman and Zervakis 2002).

Numerous drugs have been reported to affect taste functioning and the proportion of use plus the number of drugs taken because of possible drug-drug interaction, both add to the adverse side effects that involve taste impairment (Dawling and Crome 1989). Taste complaints are frequently reported with cardiovascular drugs, NSAIDs and anti depressants also because of they are often prescribed (Atkin et al 1999). So far, it remains difficult to determine the prevalence of taste impairment due of drug use because the taste complaint could be caused by the medication itself or also because of the underlying cause it is suppose to treat. More double-blind placebo controlled studies with specific medications are needed to clarify the effect of those medications on taste functioning.

Table 2a. Factors and descriptions of taste loss

Factor	Description of taste loss
Age	
Taste buds: size increase	Sensitivity loss
Saliva: amount does not change	No
Oral diseases	
Oral infections, periodontal diseases, candidosis, Burning Mouth Syndrome,	Dysgeusia, ageusia
Treatments	
Radiotherapy, chemotherapy	Dysgeusia, ageusia
Damage to neural pathways	
Surgically or pathologically	Hypogeusia (partial loss), dysgeusia or ageusia
Medical conditions	
Alzheimer, Parkinson's disease	Taste sensitivity loss is usually limited to one taste
Diabetes	Taste sensitivity is decreased for all four tastes
Critical illnesses	
Cancer	Elevated detection and recognition thresholds for all tastants
Chemotherapy	Unpleasant taste, bitter/metallic
Stroke	Hypogeusia, dysgeusia
Medication	
Antimicrobials, antihypertensives, antihyperlipidemics, antiproliferatives and corticosteroids, antirheumatics and anti- inflammatory agents, hyper-and hypoglycemic drugs, drugs to treat Parkinson's, antidepressants.	Ageusia, metallic taste, sweet taste, dysgeusia, hypogeusia

The olfactory system: peripheral to central changes

Peripheral to central changes of the olfactory system include those in the olfactory epithelium where the olfactory receptor neurons are located, the olfactory bulb and the central olfactory projections. Olfactory decline typically begins around 60 y of age and becomes more severe in people older than 70 year of age (Murphy 1993, Murphy et al 2002, Schiffman 1993, Schiffman 1997, Stevens et al 1984). However, the decline does not affect all elderly in the same way. Recent studies have shown that elderly people are a heterogeneous group when it comes to olfactory functioning; the olfactory performance of some older adults showed overlap with the young adults

(Forde and Delahunty 2004, Koskinen et al 2003a, Thomas-Danguin et al 2003). Olfactory impairment in older adults is manifested as anosmia (no sensation of smell), hyposmia (decreased sensation of smell) or dysosmia (distorted smell sensation) by having higher olfactory detection and recognition thresholds for a wide range of odors and mixtures of odors (Schiffman et al 1976) and a loss of suprathreshold odor intensity perception according to the magnitude estimation method (Schiffman 1993) (Table 2b). In addition, the ability to classify (Murphy et al 2002) and discriminate odors (Menashe et al 2003) also seems to be affected.

Olfactory epithelium

The nasal cavity in the human adult is lined with a mixture of both olfactory and non-olfactory respiratory epithelium tissues. Odor detection initiates in the olfactory epithelium in which the olfactory receptor neurons (ORNs) are surrounded by the basal cells and supporting cells. With aging, histological changes and/or losses in the olfactory epithelium may contribute to the decline in olfactory abilities.

The olfactory changes with ageing basically seem to lead to a reduction of the receptor area. For instance, at the mucosa level of the olfactory epithelium there is a decrease in cilia (the most likely binding site for odor molecules) of the ORNs and supporting cell microvilli. The receptor area is further reduced because the balance between the olfactory epithelium and non-olfactory respiratory epithelium gradually shifts in favor of the latter (Hadley et al 2004), which is manifested as an increase in the number of patches of respiratory epithelium. As a consequence, the boundary between the olfactory and respiratory epithelium becomes more irregular in older people (Paik et al 1992).

More changes that cause the receptor area to decrease include an increased ORN programmed cell death and a reduction in the total number of ORNs (Seiberling and Conley 2004) leaving the epithelium mainly with basal and supporting cells in which an increased buildup of electron-dense granules is found. As a result of receptor neuron loss, the thickness of the olfactory epithelium is reduced (Loo et al 1996, Seiberling and Conley 2004). Normally, the level of newly formed ORNs and the level of cell death are accurately regulated in the olfactory epithelium to insure the correct thickness of the epithelium during life (Murray and Calof 1999). However, with age (and injury) the neurogenesis ability and the repair capacity seems to be decreased (Seiberling and Conley 2004).

Possibly, the degeneration of the olfactory epithelium does not fully cover the often-reported age related loss of olfactory sensitivity. As it happens, a study by Loo et al

(1996) found that in aged rats the posterior part of the olfactory epithelium was well preserved and in this part together with the middle part of the epithelium, the average response to five odorants did not vary with age. These results suggest there might be other age related changes in another part of the epithelium such as the anterior or it could be that the encoded odorant information by the aged epithelium is similar for young epithelium. So far, more data are needed to extrapolate this finding to humans.

With aging the decrease in receptor area occurs through various ways. Specifically, the cilia of the ORNs decrease, olfactory epithelium is replaced by non-olfactory epithelium, the total number of ORNs decreases and the thickness of the epithelium is reduced. If and which part of the epithelium is preserved with aging and how that affects the odor capacity in elderly people needs to be further explored.

Olfactory bulb

Within the olfactory bulb, synaptic connections are formed between the axons of the ORNs and the dendrites of mitral, tufted, granule and periglomerular cells in spherical structures called glomeruli. The age related changes are found near and in the olfactory bulb and involve mostly the axons of the ORNs, the glomeruli and mitral cells.

With aging, the axons of the ORNs that reach the olfactory bulb passing through small openings (foramina) in the cribriform plate decrease in number. In addition, the size of the foramina in the cribriform plate also decreases which could contribute to the age related reduction in olfactory functioning. As a result, the obstruction of the foramina may be responsible for severed or blocked nerve networks between the epithelium and bulb (Kalmey et al 1998). More changes in the olfactory bulb involve the reduction in the number of mitral cells and glomeruli in females aged 25-102 yrs (Bhatnagar et al 1987, Meisami et al 1998). Although the specific ages for the groups are not mentioned, the decline in number of mitral cells with age was 51% in the middle aged group and 70% in the old group. These percentages were 37% and 74% respectively for the glomeruli. Both the mitral cells and glomeruli are considered the most important integrative and relay elements in the bulb and a loss of this level most likely add to the decline in olfactory sensitivity and discrimination found in elderly people (Meisami et al 1998). According to Bhatnagar et al (1987) the glomular layer thickness as well as the mitral cell size was reduced.

Magnetic resonance imaging of the olfactory bulb and tract (OBT) and temporal lobe (TL) showed that of the two, only the volume of the OBT decreased with increasing age in participants with no complains of smell loss (Yousem et al 1998). UPSIT

scores that reflect the odor identification ability were measured and no difference in scores was found between the age groups varying from 22-78 yrs old. Moreover, there was no relationship between the OBT or TL volumes with the UPSIT scores thus volumes did not decline parallel with olfactory function. Another change in the olfactory bulb concerns the existence of neurofibrillary tangles (NFTs) and senile plaques, found in people with Alzheimer Disease (AD) but also in normal aged people. Kovács et al (1999) found that in 87% of their control group of normal aged people (74±2 yrs), mitral cells developed NFTs and that the olfactory nerve fibers entered into the deeper parts of the bulb forming glomeruli outside the glomerular layer. These changes reflect the impaired olfaction in patients with AD but in normally aging people with decreased olfaction, these could represent early AD pathology in the olfactory system without suffering from dementia yet. Lastly, animal and human models show that if the olfactory nerves, bulbs and tracts -which are necessary for odor detection- are sectioned, anosmia can occur (Potter and Butters 1980).

Each structural change described above probably contributes to the age related decrease in smell identification, sensitivity and discrimination found in studies of olfaction in elderly people (Doty et al 1984). However, to link certain changes such as the reduction in axon of the ORNs, the decrease of the foramina size in cribriform plate to a specific decline in olfactory ability is not as straightforward as it seems. Further changes in the olfactory bulb are the reduction in the amount of mitral cells and the glomeruli and the formation of NFT and glomeruli outside the glomerular layer.

Central olfactory system

The neurons of the mitral and tufted cells of the olfactory bulb pass through the olfactory tract and enter the brain. There they connect to numerous locations including the piriform cortex (for odor perception and linking odor with past experiences), the entorhinal cortex, the anterior olfactory nucleus, the orbitofrontal cortex (for identification and recognition a smell), the hippocampus and amygdala (for odor memory) and the hypothalamus (serves as a feeding center) (Duffy and Chapo 2006).

Several techniques such as event related potentials (ERP) and functional magnetic resonance imaging (fMRI) have been used to study the main cortical substrates of olfactory loss. The results of studies using ERP suggest that the response in the brain to odor stimulation is reduced in amplitude and delayed in its latency in normally aging people and even more delayed in people with Alzheimer's disease. With fMRI, a decreased brain activity has been observed in response to odors in elderly compared to young people in the piriform cortex, entorhinal cortex and

amygdala (Ferdon and Murphy 2003, Suzuki et al 2001). Wang et al (2005) also observed functional changes in the central olfactory system in normal aged people with fMRI. Both young (24 ± 2 yrs) and old (66 ± 4 yrs) people had brain activity within the major olfactory brain structures. However, both the volume and the intensity of the olfactory activation of the aged adults was significantly less and this corresponded with lower UPSIT scores. The significance of the reduced activation volume in older people – whether it is related to brain atrophy – needs yet to be determined. Murphy et al (2005) aimed to find correlations between regions of interest (ROI) in the brain where activity is measured upon olfactory tasks to examine whether the pattern of these correlations is affected by aging. Compared to young adults, older adults showed no connectivity between activation in the orbitofrontal cortex and the mesial temporal lobe. This suggests that the disconnection of olfactory areas where information comes in and higher processing areas may reflect the age related changes to the olfactory system. Finally, when lesions occur in the orbitofrontal or medial thalamic, odor discrimination and odor recognition can be affected but not necessarily odor detection. Sometimes odor detection can be even more sensitive compared to control subjects (Yousem et al 1996).

In conclusion, techniques such as ERP and fMRI have been used to study olfactory losses in the brain. These show that the response to odors is reduced and delayed. In addition to the decreased brain activity, there are also functional changes such as a reduced volume and intensity of the olfactory activation that correspond with lower UPSIT scores among older adults. Another change in the olfactory system is a disconnection between certain areas that are activated upon an olfactory task. This implies that there are age related changes to the olfactory system.

Medical conditions that affect smell perception

As with taste, the conditions that are associated with olfactory complaints vary from endocrine, neurological, nutritional, local to psychiatric.

A case control study including diabetic patients showed that smell recognition is lower in people with diabetes. Other results show that smell recognition is also related to age, duration of the disease, microalbuminuria, peripheral neuropathy and the strongest with electrogustometric threshold (Le Floch et al 1993). Common neurological conditions in the aged known to affect olfactory functioning seem to be Alzheimer's, Parkinson's disease (Doty et al 1991, Schiffman et al 1976) and head trauma. Some changes that take place are seen in the olfactory bulb such as neurofibrillary tangles, senile plaques and glomeruli formed outside the glomerular layer (ectopic glomeruli) (Kovacs et al 1999) but also in the olfactory epithelium

(Jafek et al 1992). With Alzheimer's disease the losses are manifested in threshold detection, recognition, discrimination, identification and olfactory memory (Schiffman 2007). Head trauma in elderly people usually occurs because of falls and the degree of the olfactory loss corresponds with the severity of the trauma. Injuries to the frontal region or the occiput can cause severe chemosensory loss such as posttraumatic anosmia. Because the exact cause of the olfactory loss is unknown, it is hypothesized that this could be the result of shearing injuries to the olfactory nerves at the cribriform plate. In more detail, due to fibrotic scarring that occurs at the cribriform, the axons are unable to penetrate it and make contact with olfactory bulb neurons (Jafek et al 1989). By means of MR imaging in people with posttraumatic olfactory dysfunction, Yousem et al (1996) showed that most damage occurs in the olfactory bulb and tracts and the inferior frontal lobes.

Local conditions include inflammatory nasal and sinus disease such as chronic rhinosinusitis, polyps, tumors and allergic rhinitis that obstruct the nasal airflow to reach the olfactory epithelium (conductive loss). These can lead to hyposmia and/or anosmia (Schiffman 2007). In participants with chronic rhinosinusitis it is suggested that the inflammation at the olfactory epithelium combined with the reduced airflow may contribute to olfactory dysfunction (Wrobel and Leopold 2004). Upper respiratory tract infections (URI) are another common cause of neural olfactory loss where there is viral damage to the olfactory receptors. Most people with URI suffer from hyposmia, a decreased ability to smell rather than anosmia, an inability to smell. Biopsy suggests a direct insult to the olfactory epithelium, a reduced amount of olfactory receptors, which are distributed in 'patches' (Jafek et al 2002).

Medical conditions that cause olfactory dysfunction with aging include diabetes, neurodegenerative diseases, head trauma, inflammatory diseases and upper respiratory tract infections. With Alzheimer disease odor recognition, discrimination, identification, memory and detection are diminished. Head trauma could result in anosmia, depending on the severity of the brain injury and inflammatory nasal and sinus disease and upper respiratory tract infections often lead to hyposmia.

Environmental exposures

Certain airborne compounds, toxic metals, various irritant gasses and solvents can cause olfactory dysfunctions, depending on the concentration and duration of exposure. They can cause damage to the ORN but also to the olfactory bulb and the central olfactory processing system since the ORN transports substances from the epithelium directly to the brain. Because the damaged ORNs are usually unable to reach the olfactory bulb where synaptic connections take place, abnormal

connections can be formed that can lead to dysosmia (distortion of smell) (Schiffman 2007).

Cancer and other illnesses

Several groups of patients with diseases such as cancer, liver disease, minor stroke but also with chronic renal disease on hemodialysis or peritoneal dialysis are associated with olfactory complaints.

Cancer can affect olfaction if it disturbs receptor sites or interferes with neural transmission but people with cancer usually report taste disturbances (Duffy and Chappo 2006). There are few studies that have investigated olfactory changes during chemotherapy. Patients with estrogen-receptor positive breast cancer (treated or not treated) had a reduced capability for smell identification (Lehrer et al 1985). Others found that patients receiving chemotherapy -cisplatin for breast and/or lung cancer experienced changes in odor of food as unpleasant or an increased sensitivity to certain odors (Rhodes et al 1994). Furthermore, Eptstein et al (2002) treated 50 patients with a high-dose chemo/radiotherapy and hematopoietic cell transplantation and found that 26% had increased smell sensitivity whereas 8% reported a smell decrease. In a paper by Bernhardson (2009), 40 out of 518 people were studied more in depth because they reported smell changes without taste changes while receiving cancer chemotherapy. All these 40 patients reported increased sensitivity to one or more odors such as automobile exhaust fumes and hospital smells. A larger percentage, namely 41% reported taste changes with concurrent smell changes and among those decreased smell sensitivity was also reported. Several explanations have been described for the increased sensitivity to certain odors such as anticipatory nausea and vomiting, pseudo hallucination or having an increased chemical sensitivity but altogether these did not fully cover the increased olfactory sensitivity.

A number of studies find that olfactory function is compromised with liver disease such as cirrhotoses (Bloomfield et al 1999, Garrett-Laster and Jacques 1984, Temmel et al 2005). It seems that the ability for odor recognition is associated to the degree of the liver cirrhosis. It also appears that the disease is more related to a shortfall in the central nervous system than to the peripheral olfactory system. So far it is not clear why olfaction is impaired in those with the disease compared to healthy subjects within the same age range (Temmel et al 2005). However, olfaction function seemed to improve by vitamin A treatment in subjects that suffered from alcoholic cirrhosis and were vitamin A deficient (Bloomfield et al 1999, Garrett-Laster and Jacques 1984) and by restoring hepatic function after liver transplantation (Bloomfield et al 1999).

Olfactory impairment has been reported after a minor stroke and symptoms such as hyposmia, anosmia and dysosmia were experienced. Testing of the patients showed a lack of ability to detect subtle odors (Green et al 2008). Some more studies report either an increased olfactory sensitivity after a left insular stroke (Mak et al 2005) or a loss of smell for some odors but overall it seems that olfactory dysfunctions are not frequently reported following a stroke.

Chronic renal disease is another illness associated with an impaired odor perception (Frasnelli et al 2002). Griep et al (1997) found that the ability to smell was decreased in patients with chronic renal failure and this seems to get worse depending on the degree of renal impairment and the degree of accumulated uremic toxins. However, patients regained normal olfactory functioning after renal transplantation. It seems that dialysis patients often eat poorly and combined with impaired olfactory perception this may worsen the nutritional state.

In conclusion, in some cases olfaction is affected by chemotherapy and/or cancer but generally less often than taste. Smell sensitivity to certain odors can be either increased or decreased by chemotherapy. Several studies report an impaired olfaction functioning in those with liver disease but so far, the etiology is unknown. In some studies, vitamin A treatment and liver transplantation have shown to improve olfaction functioning. Other illnesses associated with a decrease in olfaction perception are stroke, although this is not frequently reported and chronic renal disease. In case of a renal disease it is reported that the status of olfaction functioning is related to the degree of renal impairment and accumulated uremic toxins. Renal transplantation may improve olfaction.

Medication that affect smell perception

Most drugs seem to affect taste rather than smell but there are several medications that have been associated with smell disturbances. In theory, drugs can alter olfactory functioning on the receptor level by for example drying the nasal mucosa, increasing nasal engorgement and changing the mucosa composition. Drug induced olfactory changes can also take place along the chemosensory neural pathway or the brain.

The most common medications among elderly that interfere with smell and have been subjected to clinical testing include antihypertensive and antiarrhythmic agents, anti-inflammatory, antimicrobial, antithyroid, bronchodilators and antiasthmatic drugs, opiates, psychopharmacologic drugs, radiation therapy and cholinergic and adrenergic agents. Most of the drugs cause anosmia (no sensation of smell) and in

Chapter 6

some cases dysosmia (distorted smell sensation) or a decreased smell threshold is reported (Schiffman and Zervakis 2002).

The effect of medicine use on chemosensory functioning is a rather complex subject. Several factors can confound the outcome of a diminished chemosensation such as the drug dose, duration of usage, the age, body weight, genetic factors of the patients, the use of other medicine or the medical problem itself that the drug is treating. This justifies the need for more quantitative placebo controlled studies to examine the effect of medication on chemosensory functioning.

Table 2b. Factors and description of smell loss

Factor	Description of smell loss
Age	
Olfactory epithelium: receptor area ↓ Olfactory bulb: axon of ORN ↓, decrease of foramina size in cribriform, mitral cells and glomeruli ↓, formation of NFT and glomeruli outside the glomerular layer Central olfactory system: reduced and delayed response to odors, reduced volume and intensity of the olfactory activation, disconnection between certain areas that are activated upon an olfactory task	Sensitivity loss
Medical conditions	
Alzheimer	Odor detection, recognition, discrimination, identification and memory ↓
Diabetes	Odor recognition ↓
Head trauma	Post traumatic anosmia (depends on injury)
Inflammatory nasal and sinus disease + upper respiratory tract infections	hyposmia.
Environmental exposures	
Certain airborne compounds, toxic metals, various irritant gasses and solvents	Dysosmia, depends on concentration and duration of exposure
Critical illnesses	
Cancer	Odor identification ↓ -depends on cancer
Cancer + chemotherapy	Changes in odors of foods –unpleasant, Increased odor sensitivity
Liver cirrhosis	Odor recognition ↓ (depends on degree cirrhosis) Hyposmia, anosmia, dysosmia
Minor stroke	Hyposmia (ability to smell ↓)
Chronic renal disease	
Medication	
Antihypertensive, antiarrhythmic agents, anti-inflammatory, antimicrobial, antithyroid, bronchodilator, antiasthmatic drugs, opiates, psychopharmacologic drugs, radiation therapy and cholinergic and adrenergic agents	Anosmia, dysosmia, odor threshold ↓

In conclusion, a range of causes has been described such as diseases, treatments, certain medication, environmental exposure (in case of smell perception) and the process of aging itself (to some extent) that can affect taste and smell performance. It is helpful to know which factors influence the performance and how they affect taste and smell functioning because in some cases such as with oral disease or cirrhosis

of the liver, the taste and respectively olfactory functioning can be improved if the disease is treated.

However, treatment of the condition in order to improve the performance is not always possible and chemosensory losses remain a fact in the lives of many elderly people. This overview has showed that we can theoretically differentiate elderly people into 3 groups; the 'normal' group with equal chemosensory performance as young people (Forde and Delahunty 2004, Koskinen et al 2003a, Thomas-Danguin et al 2003), the 'low' group with hypogeusia (diminished taste perception) and/or hyposmia (diminished olfactory perception) and the 'zero' group with ageusia and/or anosmia with no taste and/or smell perception. The next subject is to identify the appropriate tools to determine the kind and degree of taste or smell loss on an individual level.

3.2 METHODOLOGY TO ASSESS TASTE AND SMELL PERFORMANCE

Our goal in this section is to identify reliable yet practical tests or methods to assess the taste and smell perception of the elderly individual after which adequate treatment of the taste or smell dysfunction may follow. Therefore, the reliability and feasibility of several tests that assess changes in detection threshold, identification ability, supra threshold sensitivity and/or preference are discussed.

Taste

Current methodology

Taste tests that assess an alteration in taste sensitivity include liquid dilutions (Henkin and Christiansen 1967) (Gudziol and Hummel 2007), tablets (Ahne et al 2000), edible wafers (Hummel et al 1997b) or taste strips (Landis et al 2009, Mueller et al 2003, Nordin et al 2007). Electrogustometry estimates taste detection thresholds (Table 3a).

Table 3a. Test-retest correlations and applicability of several methods that assess taste detection threshold, suprathreshold sensitivity, identification ability or preference

Method	Assessment	Reliability	Applicability	Reference
Maximum likelihood adaptive staircase	Detection threshold	$r=0.58-0.75$	Clinic	Linschoten et al 2001
Electrogustometry	Detection threshold	$r=0.78$ with 125 mm electrode	Clinic	Nicolaescu et al 2005
Three drop test	Identification ability	As recognition threshold $r=0.71$	Laboratory	Ahne et al 2000
Taste tablets	Identification ability	$r=0.69$ $r=0.66$ vs 3 drop test	Clinic	Ahne et al 2000
Taste strips	Identification ability	$r=0.68$ $r=0.67$ vs. 3 drop test	Clinic Laboratory Outside laboratory	Mueller et al 2003
Free-modulus magnitude estimation procedure	Suprathreshold sensitivity	$r=0.64-0.72$	Laboratory	Mattes 1988
Sample modification task	Preference	$r>0.72$	Laboratory	Mattes 1988

Maximum-likelihood adaptive staircase method

The maximum-likelihood adaptive staircase method can be used to measure detection sensitivity. Linschoten et al (2001) found significant correlations of $r=0.58$ to $r=0.75$ of individual NaCl threshold responses between several sessions (four in total). These correlations indicate good test-retest reliability between the responses. The authors concluded that the maximum-likelihood adaptive staircase method gives estimates of thresholds that are stable within individuals over time and they recommend this method for use in clinical testing.

Electrogustometry

Electrogustometry can be used to estimate taste detection thresholds before and after different treatment conditions or surgery and also to detect side differences of the tongue's taste function (Stillman et al 2003). It does not specifically identify basic

taste. Upon measuring electrogustometric threshold responses, larger electrodes (125 mm) show a better test-retest correlation ($r=0.78$, $p<0.00$) compared to 25 mm electrodes ($r=0.46$, $p<0.05$). This suggests that threshold responses are more stable when measured with larger electrodes (Nicolaescu et al 2005).

Free-modulus magnitude estimation procedure

Regarding the reliability of suprathreshold sensitivity responses we did not find many studies. Perceived intensity responses obtained by a free-modulus magnitude estimation procedure correlated fairly well for fruit beverages ($r=0.64$ for day 1-day 7 and $r=0.72$ for day 1–day 28) but not for aqueous sucrose solutions and chocolate beverages (Mattes 1988).

Three-drop forced choice procedure

This procedure assesses the deficiency of the basic tastes. Using the three-drop forced choice procedure with liquid taste dilutions to establish a performance score (determined by the mean recognition threshold of the four tastes) among 101 volunteers (21-81 y) showed a significant correlation ($r=0.71$, $p<0.001$) between two sessions (Ahne et al 2000). A disadvantage of this test is its practical use; the solutions have to be prepared freshly, their shelf life is variable and they are not easily transported outside the laboratory. All these factors limit its use for the routine clinical testing.

Tasting tablets

Taste tablets showed a test-retest correlation of 0.69 ($p<0.001$) between two sessions in which scores of correctly identified dilutions of the four tastes were compared. This result is comparable to other gustatory tests (Mattes 1988). In addition, when the outcome of the taste tablets test were correlated with the three-drop test performance, results show that the tablets were appropriate to measure taste sensitivity changes ($r=0.66$, $p<0.001$) (Ahne et al 2000). The tablets are easy to use, can be self-administered, have a long shelf life and are appropriate for clinical testing.

Edible wafers

Differences between taste quality identification measured with wafers (flavored wafers made from water and flour) were only found while testing regionally and not for whole mouth testing which is needed for 'everyday' taste experience ($n=100$, 20-89 y) (Hummel et al 1997b). This implies that edible wafers do measure whole mouth taste perception alterations. Although the wafers have many advantages, such as

easy to use, a 2-3 yr shelf life and can be used in a clinical setting, no test-retest correlation was found in the literature.

Taste strips

Repeated measures with taste strips (paper filters impregnated with tastants) to identify the four basic taste qualities show a good reproducibility when tried in 69 subjects ($r=0.68$). Also when these results were compared to the three-drop method ($r=0.67$) (Mueller et al 2003). Taste strips are convenient in administration, easy to transport to places outside the laboratory, useful in a clinical setting, can be used for localized testing (on each side of the tongue) with a precise amount of tastant, have a long shelf-life, a short testing time of approximately 8 minutes and normative data is available (Landis et al 2009). This test discriminates between subjects with normogeusia, ageusia and hypogeusia (Mueller et al 2003, Smutzer et al 2008).

Edible taste strips

Another version of taste strips, namely edible taste strips seem to be a more sensitive method for determining recognition thresholds than an aqueous sip and spit taste test (Smutzer et al 2008). The taste recognition threshold for sweet as examined by the taste strips showed a smaller variability and was 1 magnitude lower when compared to the results obtained with an aqueous taste test ($3.3 \mu\text{mol}$ vs $172 \mu\text{mol}$) ($n=41, 18-58\text{y}$). Although this seems a sensitive method and has similar advantages as the non-edible version, so far no test-retest correlation is available for this version to evaluate its reliability.

Sample modification task

Mattes (1988) found good test-retest correlations between responses for preferred sucrose concentrations in aqueous solutions, fruit beverages and chocolate beverages obtained via a sample modification task. The correlations between group responses for day 1 and day 7, plus day 1 and day 28 were all higher than 0.72.

To conclude, it is essential in clinical testing that people with raised detection thresholds be easily detected. The maximum likelihood method shows good test-retest correlations when estimating detection thresholds responses. Overall, the identification ability tests show good and comparable test-retest reliability but they differ when it comes to their usefulness. Compared to liquid dilutions, wafers and tablets which are either not commercially available or lack available normative data, taste strips seem convenient and useful in a clinical setting to measure taste function of the individual elderly.

Smell

Current methodology

Psychophysical olfactory tests are those in which stimuli are presented and the subject has to report whether these can be perceived (e.g. detected, discriminated or identified). These tests can be subdivided into two classes: threshold and suprathreshold tests. Examples of tests that assess the detection threshold are the Sniffin' Sticks test, the Connecticut Chemosensory Clinical Research Center (CCCRC) test (both contain an odor threshold component) or the Smell Threshold test, which includes bottles with strips of blotted paper within. Furthermore, detection threshold tests use several strategies to present subjects with dilutions to measure detection sensitivity of an odorant. Used methods are the ascending method of limits (AML), the staircase procedure (SS), method of constant stimuli and the maximum-likelihood adaptive staircase methods introduced by (Linschoten et al 2001). This last procedure is designed to minimize the number of trials needed to find a reliable threshold value plus to lower error variance in the final threshold value.

Suprathreshold tests include the use of rating scales, magnitude estimation and odor identification tests. There are more than a dozen tests to determine odor identification including the Sniffin' sticks test, CCCRC test, the European Test of Olfactory Capabilities (ETOC), San Diego Odor Identification Test, the University of Pennsylvania Smell Identification Test (UPSIT) and the Cross-Cultural Smell Identification Test (CC-SIT) (Table 3b).

Table 3b. Test-retest correlations and applicability of several methods that assess odor detection threshold, suprathreshold sensitivity, identification ability or preference

Method	Assessment	Reliability	Applicability	Reference
Sniffin' Sticks (Single Staircase)	Detection	r=0.43-	Clinic	Hummel et al (1997a), Lötsch et al (2004), Albrecht et al (2008) Hummel et al (1997a)
	threshold	0.85	Research	
	Identification	r=0.73	Industrial	
Sniffin' Sticks Meth. Constant Stimuli	Detection threshold	r=0.79	Clinic	Lötsch et al (2004)
Sniffin' Sticks (5 item)	Identification	0.77	Clinic	Mueller and Renner (2006)
CCCRC	Detection threshold	r=0.36	Clinic	Hummel et al (1997a)
	Identification	r=0.60- 0.92		Hummel et al (1997a), Toledano et al (2007)
Maximum likelihood adaptive staircase	Detection threshold	0.26-0.86	Clinic	Linshoten et al (2001)
European test of Olfactory Capabilities	Detection threshold	r=0.89- 0.92	Clinic Laboratory	Thomas-Danguin et al (2003)
	Identification			
SDOIT	Identification	r=0.85	Research: epidemiological studies	Krantz et al (2009)
UPSIT	Identification	r=0.92- 0.95	Clinic Outside laboratory	Doty et al (1985)
CC-SIT	Identification	r=0.73	Clinic	Doty et al (1995)
Two alternative forced choice	Detection threshold	r=0.69		Frank et al (2003)

Sniffin' Sticks test

The Sniffin' Sticks test is well recognized for combined testing of olfactory threshold, discrimination and identification. Test-retest correlations between sessions for the detection threshold component of the Sniffin' Sticks test -measured using a single staircase (SS) procedure- vary from 0.61 (n=104, 18-84 yrs) Hummel et al (1997a) to

0.82 ($p < 0.001$) ($n = 100$, 19-79 yrs) Lötsch et al (2004). The last study also used the method of constant stimuli (MCS in Table 3b) and found correlations between detection thresholds of $r = 0.79$ ($p < 0.001$). The advantage of the method of constant stimuli is a shorter and less variable performing time compared to the staircase method, which is useful in situations where routine testing is performed. Another more recent study that used the Sniffin' Sticks test found test-retest correlations of detection threshold values in the range of 0.43-0.85 ($n = 64$, $p < 0.01$) when measured repeatedly across 4 time points (Albrecht et al 2008). This study concluded that olfactory detection threshold test of the Sniffin' Sticks test is suitable for repeated testing more than once a day and over a long period of time during experimental or clinical studies.

Regarding the reliability of the identification component of the Sniffin' Sticks test, Hummel et al (1997) found a test-retest correlation of 0.73. A shorter version that used five items from the Sniffin' Sticks identification test, showed a test-retest reliability of 0.77 ($p < 0.01$) ($n = 21$) (Mueller and Renner 2006). Comparing the results of the short version with the traditional 16-item identification Sniffin' Sticks and the Brief Smell Identification test, revealed correlations of 0.61 and 0.77 respectively. Although this test seems useful as a short screening test and can be performed in 3 minutes, it can only confirm the existence of normosmia and mild hyposmia.

Based on the literature found, the Sniffin' Sticks test proves reliable. In addition, normative data is available based on more than 3000 subjects (Hummel et al 2007). The composite score of threshold, discrimination and identification (TDI) are used to classify subjects as normosmic, hyposmic or anosmic.

Connecticut Chemosensory Clinical Research Center (CCCRC) test

The CCCRC consists of two tests, an odor detection threshold determination (of *n*-butanol threshold) and an odor identification test. Hummel et al (1997a) found correlations of 0.36 for detection threshold values and 0.60 for odor identification. A recent study determined the reliability of the CCCRC and compared its validity with UPSIT (Toledano et al 2007). In 60 adult patients with nasal polyposis they found a reliability of 0.92 and a validity index of 95% and concluded the CCCRC is a valid test. They also reported a sensitivity of 86%, which means that the probability of missing a person with nasal polyposis is 14% and a specificity of 94% meaning that the probability of wrongly classifying a person as having polyposis is 6%.

Maximum-likelihood method and Two-alternative forced choice procedure

Linshoten et al (2001) compared the ascending methods of limits, staircase method and the maximum-likelihood method in the measurement of butyl alcohol thresholds. They concluded that the maximum likelihood methods did not need the fewest trials but it measured the detection threshold with a higher precision compared to the other methods. The correlation coefficients between detection thresholds values as measured with the maximum-likelihood methods (on four occasions) were in the range of 0.26-0.86 (n=27, 22-57 yrs). The order of strategies to obtain a more reliable detection threshold value with a minimal error variance in the final value, would be the adaptive maximum-likelihood procedure > the staircase procedure (SS) > ascending methods of limits (AML) (Doty 2006). The two-alternative forced choice (2AFC) method is an almost bias-free measure of sensitivity. This task was used in a study by Frank et al (2003) to assess the butanol threshold with 11 concentration steps and showed to have a test-retest correlation coefficient of 0.69.

The European test of Olfactory Capabilities (ETOC)

The ETOC combines a suprathreshold detection task with and an identification task (Thomas-Danguin et al 2003). It is a relatively rapid test of about 20 minutes, has been validated in 3 European countries (France, The Netherlands and Sweden) and showed a re-test correlation of 0.92 in France and 0.89 in Sweden. The test has proven to be sensitive to age related changes in odor detection and identification as elderly people showed to have poorer olfactory abilities compared to young people. It has shown to distinguish subjects with normal olfactory performance from those with anosmia and hyposmia based on a composite score (detection plus identification) and is considered useful for clinical evaluation (Koskinen et al 2004). In spite of this, the test is not fully validated in other European countries or elsewhere in the world, which could affect the measured outcome.

San Diego Odor Identification test (SDOIT)

The SDOIT measures odor identification using 8 common household odorants. In a recent study, Krantz et al (2009) showed that the test has a good test-retest reliability of 0.85 (n=90, 50-70 y) in an adult population. The authors concluded that the test is useful for longitudinal studies examining change in olfactory impairment. Although the test is limited in defining gradations of olfactory functioning, it is able to classify subjects as impaired or abnormal. Regarding its feasibility, the test has a standardized protocol and takes 15 minutes to perform.

University of Pennsylvania Smell Identification Test (UPSIT)

The UPSIT is a widely used olfactory identification test in the world. It includes four booklets containing 10 odorants apiece, one odorant per page thus 40 in total. This test showed high test-retest reliability upon measuring the ability to identify odors, namely $r=0.92$ for the long term (6 months) and $r=0.95$ ($n=67$) for short term (2 weeks) (Doty et al 1985). Norms are based upon scores from over 1600 subjects and subjects can be divided into anosmics, hyposmics and normosmics based on their performance. The test is commercially available, can be self administered, can be sent through the mail, is useful for application outside the laboratory setting and takes about 15 minutes.

Cross-Cultural Smell Identification Test (CC-SIT)

This test is a shorter version (12 items) of the UPSIT (Doty et al 1996) in which items from the UPSIT were selected that are familiar to most people from North and South America, Europe and Asia. A test-retest reliability of 0.73 was found (Doty et al 1995). Normative data is available and based on their performance subjects can be divided into anosmics, hyposmics and normosmics. This test is valid for clinical evaluation and takes 5 minutes to perform.

Scales for hedonic judgment of odors

Ratings scales are used identify an amount for pleasantness usually as a function of the odorant's concentration. Upon comparison of five common acceptance and preference methods (9-point hedonic, labeled affective magnitude and unstructured line scales, best-worst scaling and preference raking), Hein et al (2008) found that the best-worst scaling was the most discriminative but not the most practical. The 9-point hedonic scale was found to be more practical and is used to measure pleasantness perception of odors at several concentrations in a study by Koskinen et al (2003a). The typical descriptors used to mark the extremes of this scale are very unpleasant – extremely pleasant.

Suprathreshold intensity ratings reliability

Very few studies were found on the test-retest correlations with suprathreshold ratings. One study revealed correlations of 0.76 (Doty et al 1995).

To conclude, the effectiveness of a test relies on its level of reliability (consistency, stability), validity (correctly measures what it is supposed to measure) and feasibility. We have been able discuss the reliability and feasibility of several tests but to a less extent the validity. It seems that validity data for the majority of olfactory tests is simply not available (Doty 2006). Although the reliability varied among the detection

tests and the identification tests, overall it seemed good. The variability in correlation coefficients between certain tests could be because the reliability is positively correlated with the length of the test (Doty 2006). This is evident when comparing the shorter 5-item version of the Sniffin' test with the established 16-item, as the reliability of the shorter version was lower. This was also in the case for the UPSIT versus the CC-SIT, where the reliability of the CC-SIT was lower. Thus, the differences in reliability may be due to the number of items and thus time.

To assess the odor detection threshold, there are several tests and the final choice depends on the appropriateness for elderly. The Sniffin' Sticks using the method of constant stimuli would be suitable because of its shorter and less variable performing time. Based on the finding that it measures with higher precision, the method of maximum-likelihood would be another choice. Both methods are useful in a clinical setting. From our own experience, the ETOC would be a practical option for the elderly but it requires further validation.

To assess odor identification, the Sniffin' Sticks identification component, UPSIT or its shorter version CC-SIT would be appropriate. All are widely recognized, easy to use, suitable for clinical settings and divide subjects into anosmics, hyposmics and normosmics.

Lastly, it must be noted however that identification is a cognitive demanding task and apart from olfactory function other factors such as proficiency in semantic memory, intensity perception and personality style may influence the outcome (Cain et al 1998, Larsson et al 2000).

3.3 A PROPOSED FUTURE STRATEGY FOR FLAVOR ENHANCEMENT OF FOOD

“A single dish cannot satisfy the tastes of a hundred people” -Chinese proverb

Based on our findings, we no longer support the idea that a standardized flavor enhancement is the right approach to increase liking and/or food intake as hypothesized in chapter 1. The remaining question is now if and how to continue with flavor enhancement of food for frail and undernourished institutionalized and free-living elderly to stimulate food intake since a uniform approach proved ineffective. We think that flavor enhancement of food as part of the treatment and prevention of undernutrition still holds potential but only as a more individual and tailored approach. The reason for suggesting this approach is the following. A number of studies have provided evidence that elderly can be a heterogeneous group where it comes to their taste and/or smell functioning and can be differentiated as such into at least 3 groups: the ‘normal’ group with equal chemosensory performance as young people (Forde and Delahunty 2004, Koskinen et al 2003a, Thomas-Danguin et al 2003), the ‘low’ group with hypogeusia (diminished taste perception) and/or hyposmia (diminished olfactory perception) and the ‘zero’ group with ageusia and/or anosmia with no taste and/or smell perception. Depending on the degree of their taste and smell loss, subjects could belong to combinations of groups. Thus, before implementing flavor enhancement of foods as part of a treatment or prevention of undernutrition, it is important to first characterize the elderly people into different groups so that the right approach may be used in each group (see Figure 2).

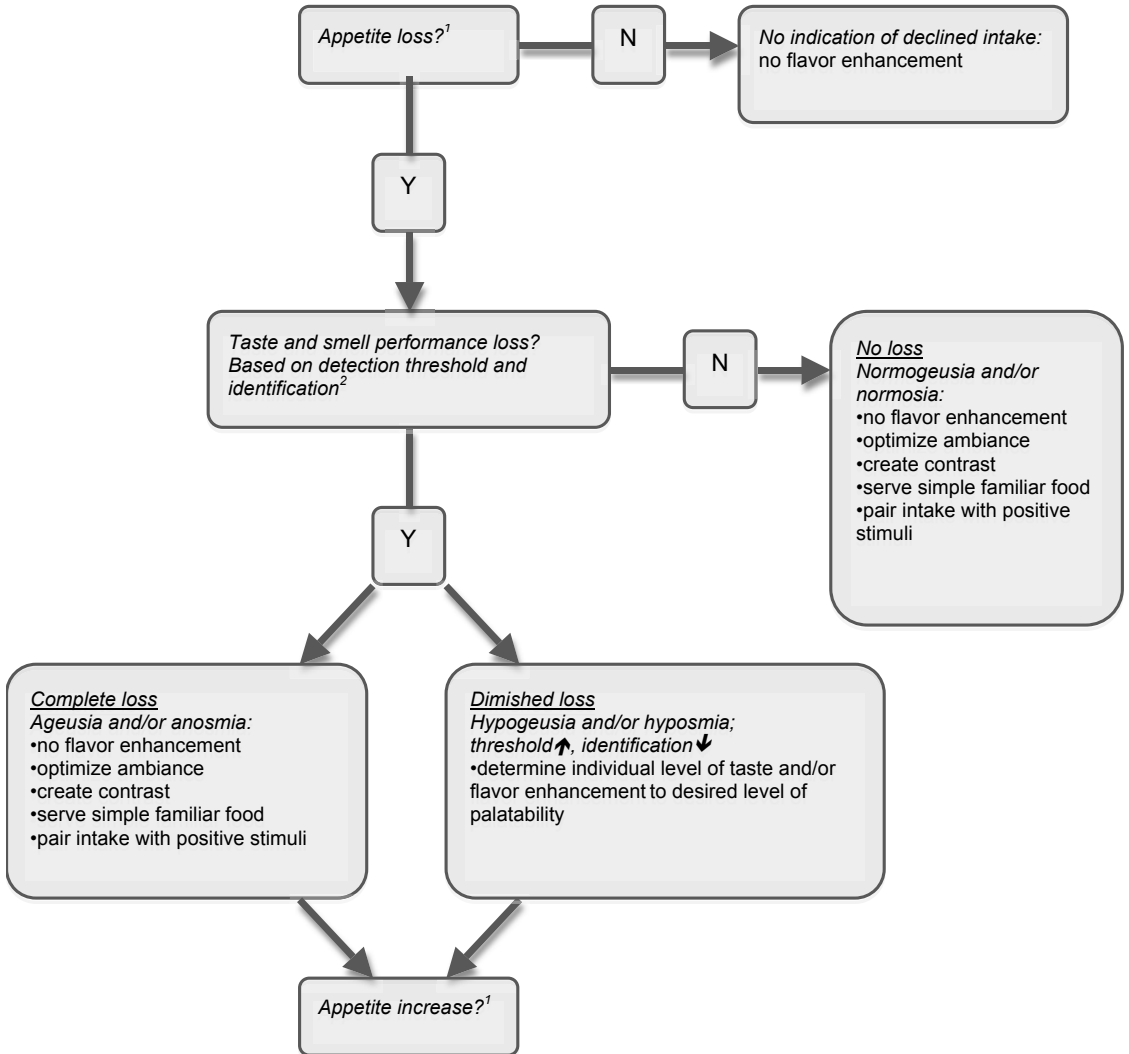


Figure 2. Flow chart for a proposed future strategy of flavor enhancement of food as part of the treatment and prevention of undernutrition in elderly

¹ Simplified nutritional appetite questionnaire (SNAQ)

² Methods: the maximum likelihood method for taste threshold detection, taste strips for taste identification ability, Sniffin sticks MCS or maximum likelihood method for odor threshold detection, Sniffin' sticks, UPSIT & CC-SIT for odor identification

As shown in Figure 2, the characterization starts with selecting those elderly that have an indication of a diminished appetite predicting a low food intake. This can be determined with the 4-item Simplified Nutritional Appetite Questionnaire (SNAQ) (Wilson et al 2005). This is a short and clinically efficient tool that assesses appetite and predicts weight loss in institutionalized elderly. If appetite loss were demonstrated, the next step would be to determine the taste and smell performance based on the assessment of the taste and odor detection threshold and identification ability with the appropriate tests.

These tests should be reliable and feasible (see methodology to assess taste and smell performance). To assess taste detection threshold, the maximum-likelihood or the 2AFC method seem suitable. To determine taste identification ability the taste strips are described as convenient, useful in a clinical setting and discriminate between subjects with normogeusia, ageusia and hypogeusia. For the assessment of odor detection threshold, the Sniffin' Sticks using the method of constant stimuli would be suitable or the method of maximum-likelihood. Lastly, for odor identification ability the Sniffin' Sticks identification component, UPSIT or its shorter version CC-SIT would be appropriate since all are widely recognized, easy to use, suitable for clinical settings and able to divide subjects into anosmics, hyposmics and normosmics.

Once the taste and smell performance of elderly subjects are correctly characterized, elderly in the 'normal' group will be excluded from treatment with flavor enhancement. Elderly in the 'low' group suffering from hypogeusia and/or hyposmia may perhaps benefit from an increased concentration of tastants and/or extra flavors. On an individual level it can be determined which of the basic tastes and/or flavors need to be enhanced and how much is perceived as desirable, since thresholds and identification ability may vary between subjects. Thus, the strategy for this group is to determine the flavor enhancement treatment on an individual level by means of trial and error, in order to improve intake and/or liking. For people with ageusia and/or anosmia the use of extra taste and/or flavor enhancement is obviously of no use and other options to increase intake and/or liking should be considered. One strategy would include the stimulation of other senses such as vision by creating more contrast between their food and their environment. For example, the illumination can be increased and a greater contrast in color between the foods on their plate can be offered. Another strategy, which has been studied recently, would be to optimize the ambience during mealtime by having family style meals instead of tray service meals. This has shown to improve quality of life and food intake (Nijs et al 2006). More strategies to increase liking of foods would be to serve simple-cooked familiar food (Laureati et al 2005) or to pair consumption of the food with a positive stimuli or an

event (Mela 2000). Thus, the strategies for this group –which could also be applied to the ‘normal’ group - are more related to psychological and social environment interventions.

During and after the treatment, appetite and liking should be assessed to verify if the above-described approaches stimulate appetite. If flavor enhancement proves ineffective to stimulate appetite and intake but does affect liking in the in the ‘low’ group, the treatment could continue as an increased hedonic perception adds to the quality of life. If the treatment shows to have no effect at all, it is of no use to continue with flavor enhancement and this group may also benefit from the same psychological and social environment interventions as the ‘zero’ group.

In case of treatable diseases, strategies should intervene more on the physiological level such as treating Burning Mouth Syndrome by means of ECT. This could indirectly improve taste but more research is needed to confirm this. Tongue brushing of lightly-coated tongues of elderly people has also shown to improve taste sensitivity. Olfaction functioning seems to improve by treating liver cirrhosis with vitamin A, by restoring hepatic function after liver transplantation or upon renal transplantation in case of chronic renal failure but the last two procedures are more substantial.

In conclusion, our hypothesis that a standardized flavor enhancement treatment is the right approach to increase food intake in the elderly people with diminished appetite cannot be accepted. A more individual tailored approach of flavor enhancement of foods to increase food intake might still be considered. We proposed a strategy and a flow chart to incorporate flavor enhancement as part of the treatment and prevention of undernutrition. Several steps in the flow chart, however, should still be validated and tested in practice.

REFERENCES

- Ahne G, Erras A, Hummel T, Kobal G. Assessment of gustatory function by means of tasting tablets. *Laryngoscope* 2000;110:1396-1401
- Albrecht J, Anzinger A, Kopietz R, Schopf V, Kleemann AM, Pollatos O, Wiesmann M. Test-retest reliability of the olfactory detection threshold test of the Sniffin' sticks. *Chem Senses* 2008;33:461-467
- Arey LB, Tremaine MJ, Monzingo FL. The numerical and topographical relations of the taste buds to human circumvallate papillae throughout the life span. *Anat Rec* 1935;64:9-25
- Arvidson K. Location and variation in number of taste buds in human fungiform papillae. *Scand J Dent Res* 1979;87:435-442
- Atkin PA, Veitch PC, Veitch EM, Ogle SJ. The epidemiology of serious adverse drug reactions among the elderly. *Drugs Aging* 1999;14:141-152
- Barry MA, Frank ME. Response of the gustatory system to peripheral nerve injury. *Exp Neurol* 1992;115:60-64
- Bartoshuk LM, Desnoyers S, Hudson C, Marks L, O'Brien M, Catalanotto F, Gent J, Williams D, Ostrum KM. Tasting on localized areas. *Ann N Y Acad Sci* 1987;510:166-168
- Bellisle F, Dalix AM, Chappuis AS, Rossi F, Fiquet P, Gaudin V, Assoun M, Slama G. Monosodium glutamate affects mealtime food selection in diabetic patients. *Appetite* 1996;26:267-275
- Bellisle F, Monneuse MO, Chabert M, Larue-Achagiotis C, Lanteaume MT, Louis-Sylvestre J. Monosodium glutamate as a palatability enhancer in the European diet. *Physiol Behav* 1991;49:869-873
- Ben-Aryeh H, Miron D, Szargel R, Gutman D. Whole-saliva secretion rates in old and young healthy subjects. *J Dent Res* 1984;63:1147-1148
- Ben-Aryeh H, Shalev A, Szargel R, Laor A, Laufer D, Gutman D. The salivary flow rate and composition of whole and parotid resting and stimulated saliva in young and old healthy subjects. *Biochem Med Metab Biol* 1986;36:260-265
- Bergdahl M, Bergdahl J. Burning mouth syndrome: prevalence and associated factors. *J Oral Pathol Med* 1999;28:350-354
- Bernhardson BM, Tishelman C, Rutqvist LE. Olfactory changes among patients receiving chemotherapy. *Eur J Oncol Nurs* 2009;13:9-15
- Berteretche MV, Dalix AM, d'Ornano AM, Bellisle F, Khayat D, Faurion A. Decreased taste sensitivity in cancer patients under chemotherapy. *Support Care Cancer* 2004;12:571-576
- Bhatnagar KP, Kennedy RC, Baron G, Greenberg RA. Number of mitral cells and the bulb volume in the aging human olfactory bulb: a quantitative morphological study. *Anat Rec* 1987;218:73-87
- Birch LL. Development of food preferences. *Annu Rev Nutr* 1999;19:41-62
- Bloomfield RS, Graham BG, Schiffman SS, Killenberg PG. Alterations of chemosensory function in end-stage liver disease. *Physiol Behav* 1999;66:203-207
- Boucher Y, Berteretche MV, Farhang F, Arvy MP, Azerad J, Faurion A. Taste deficits related to dental deafferentation: an electrogustometric study in humans. *Eur J Oral Sci* 2006;114:456-464

- Breslin PA, Tharp CD. Reduction of saltiness and bitterness after a chlorhexidine rinse. *Chem Senses* 2001;26:105-116
- Bull TR. Taste and the Chorda Typani. *J Laryngol Otol* 1965;79:479-493
- Cain WS, de Wijk R, Lulejian C, Schiet F, See LC. Odor identification: perceptual and semantic dimensions. *Chem Senses* 1998;23:309-326
- Carson JA, Gormican A. Taste acuity and food attitudes of selected patients with cancer. *J Am Diet Assoc* 1977;70:361-365
- Catalanotto FA, Bartoshuk LM, Ostrom KM, Gent JF, Fast K. Effects of anesthesia of the facial nerve on taste. *Chem Senses* 1993;18
- Cerchiari DP, de Moricz RD, Sanjar FA, Rapoport PB, Moretti G, Guerra MM. Burning mouth syndrome: etiology. *Braz J Otorhinolaryngol* 2006;72:419-423
- Chauncey HH, Muench ME, Kapur KK, Wayler AH. The effect of the loss of teeth on diet and nutrition. *Int Dent J* 1984;34:98-104
- Cowart BJ, Yokomukai Y, Beauchamp GK. Bitter taste in aging: compound-specific decline in sensitivity. *Physiol Behav* 1994;56:1237-1241
- Dawling S, Crome P. Clinical pharmacokinetic considerations in the elderly. An update. *Clin Pharmacokinet* 1989;17:236-263
- de Araujo IE, Rolls ET, Kringelbach ML, McGlone F, Phillips N. Taste-olfactory convergence, and the representation of the pleasantness of flavour, in the human brain. *Eur J Neurosci* 2003;18:2059-2068
- De Castro JM. Age-related changes in spontaneous food intake and hunger in humans. *Appetite* 1993;21:255-272
- De Castro JM. Age-related changes in the social, psychological, and temporal influences on food intake in free-living, healthy, adult humans. *J Gerontol A Biol Sci Med Sci* 2002;57:M368-377
- de Graaf C, Kramer FM, Meiselman HL, Leshner LL, Baker-Fulco C, Hirsch ES, Warber J. Food acceptability in field studies with US army men and women: relationship with food intake and food choice after repeated exposures. *Appetite* 2005;44:23-31
- de Graaf C, Polet P, van Staveren WA. Sensory perception and pleasantness of food flavors in elderly subjects. *J Gerontol* 1994;49:P93-99
- DeWys WD, Walters K. Abnormalities of taste sensation in cancer patients. *Cancer* 1975;36:1888-1896
- Doty RL. Olfactory dysfunction and its measurement in the clinic and workplace. *Int Arch Occup Environ Health* 2006;79:268-282
- Doty RL, Bromley SM. Effects of drugs on olfaction and taste. *Otolaryngol Clin North Am* 2004;37:1229-1254
- Doty RL, Marcus A, Lee WW. Development of the 12-item Cross-Cultural Smell Identification Test (CC-SIT). *Laryngoscope* 1996;106:353-356

Chapter 6

Doty RL, McKeown DA, Lee WW, Shaman P. A study of the test-retest reliability of ten olfactory tests. *Chem Senses* 1995;20:645-656

Doty RL, Newhouse MG, Azzalina JD. Internal consistency and short-term test-retest reliability of the University of Pennsylvania Smell Identification Test. *Chem Senses* 1985;10:297-300

Doty RL, Perl DP, Steele JC, Chen KM, Pierce JD, Jr., Reyes P, Kurland LT. Olfactory dysfunction in three neurodegenerative diseases. *Geriatrics* 1991;46 Suppl 1:47-51

Doty RL, Shaman P, Applebaum SL, Giberson R, Siksorski L, Rosenberg L. Smell identification ability: changes with age. *Science* 1984;226:1441-1443

Duffy VB, Chapo AK. Smell, taste, and somatosensation in aging. In *Geriatric Nutrition*. pp115-162. Jones and Bartlett Publishers 2006.

Epstein JB, Phillips N, Parry J, Epstein MS, Nevill T, Stevenson-Moore P. Quality of life, taste, olfactory and oral function following high-dose chemotherapy and allogeneic hematopoietic cell transplantation. *Bone Marrow Transplant* 2002;30:785-789

Essed NH, Kleikers S, van Staveren WA, Kok FJ, de Graaf C. No effect on intake and liking of soup enhanced with mono-sodium glutamate and celery powder among elderly people with olfactory and/or gustatory loss. *Int J Food Sci Nutr* 2009a;22:1-12

Essed NH, Oerlemans P, Hoek M, Van Staveren WA, Kok FJ, de Graaf C. Optimal preferred MSG concentration in potatoes, spinach and beef and their effect on intake in institutionalized elderly people. *J Nutr Health Aging* 2009b;13:769-775

Essed NH, van Staveren WA, Kok FJ, de Graaf C. No effect of 16 weeks flavor enhancement on dietary intake and nutritional status of nursing home elderly. *Appetite* 2007;48:29-36

Ferdon S, Murphy C. The cerebellum and olfaction in the aging brain: a functional magnetic resonance imaging study. *Neuroimage* 2003;20:12-21

Fetting JH, Wilcox PM, Sheidler VR, Enterline JP, Donehower RC, Growchow LB. Tastes associated with parenteral chemotherapy for breast cancer. *Cancer Treatment Reports* 1995;69:1249-1251

Forde CG, Delahunty CM. Understanding the role cross-modal sensory interactions play in food acceptability in younger and older consumers. *Food Quality and Preference* 2004;15:715-727

Frank RA, Dulay MF, Gesteland RC. Assessment of the Sniff Magnitude Test as a clinical test of olfactory function. *Physiol Behav* 2003;78:195-204

Frasnelli JA, Temmel AF, Quint C, Oberbauer R, Hummel T. Olfactory function in chronic renal failure. *Am J Rhinol* 2002;16:275-279

Fukunaga A. Age-related changes in renewal of taste bud cells and expression of taste cell-specific proteins in mice. *Kokubyo Gakkai Zasshi* 2005;72:84-89

Garrett-Laster M RR, Jacques PF. Impairment of taste and olfaction in patients with cirrhosis: the role of vitamin A. *Hum Nutr Clin Nutr* 1984;38:203-214

Ghezzi EM, Ship JA. Aging and secretory reserve capacity of major salivary glands. *J Dent Res* 2003;82:844-848

- Ghezzi EM, Wagner-Lange LA, Schork MA, Metter EJ, Baum BJ, Streckfus CF, Ship JA. Longitudinal influence of age, menopause, hormone replacement therapy, and other medications on parotid flow rates in healthy women. *J Gerontol A Biol Sci Med Sci* 2000;55:M34-42
- Gorshein D. Posthypophysectomy taste abnormalities: their relationship to remote effects of cancer. *Cancer* 1977;39:1700-1703
- Green TL, McGregor LD, King KM. Smell and taste dysfunction following minor stroke: a case report. *Can J Neurosci Nurs* 2008;30:10-13
- Griep MI, Van der Niepen P, Sennesael JJ, Mets TF, Massart DL, Verbeelen DL. Odour perception in chronic renal disease. *Nephrol Dial Transplant* 1997;12:2093-2098
- Grushka M, Epstein JB, Gorsky M. Burning mouth syndrome. *Am Fam Physician* 2002;65:615-620
- Gudziol H, Hummel T. Normative values for the assessment of gustatory function using liquid tastants. *Acta Otolaryngol* 2007;127:658-661
- Hadley K, Orlandi RR, Fong KJ. Basic anatomy and physiology of olfaction and taste. *Otolaryngol Clin North Am* 2004;37:1115-1126
- Heckmann JG, Stosel C, Lang CJ, Neundorfer B, Tomandl B, Hummel T. Taste disorders in acute stroke: a prospective observational study on taste disorders in 102 stroke patients. *Stroke* 2005;36:1690-1694
- Hein KA, Jaeger SR, Carr TB, Delahunty CM. Comparison of five common acceptance and preference methods. *Food Qual Prefer* 2008;19:651-661
- Helms JA, Della-Fera MA, Mott AE, Frank ME. Effects of chlorhexidine on human taste perception. *Arch Oral Biol* 1995;40:913-920
- Henkin RI. Drug-induced taste and smell disorders. Incidence, mechanisms and management related primarily to treatment of sensory receptor dysfunction. *Drug Saf* 1994;11:318-377
- Henkin RI, Christiansen RL. Taste thresholds in patients with dentures. *J Am Dent Assoc* 1967;75:118-120
- Hummel T, Erras A, Kobal G. A test for the screening of taste function. *Rhinology* 1997b;35:146-148
- Hummel T, Kobal G, Gudziol H, Mackay-Sim A. Normative data for the "Sniffin' Sticks" including tests of odor identification, odor discrimination, and olfactory thresholds: an upgrade based on a group of more than 3,000 subjects. *Eur Arch Otorhinolaryngol* 2007;264:237-243
- Hummel T, Sekinger B, Wolf SR, Pauli E, Kobal G. 'Sniffin' sticks': olfactory performance assessed by the combined testing of odor identification, odor discrimination and olfactory threshold. *Chem Senses* 1997a;22:39-52
- Jafek BW, Eller PM, Esses BA, Moran DT. Post-traumatic anosmia. Ultrastructural correlates. *Arch Neurol* 1989;46:300-304
- Jafek BW, Eller PM, Johnson EW, Chapman MM, Filley CM. Ultrastructural changes in the olfactory epithelium in Alzheimer's disease. *Am J Rhinol* 1992;6:219-225
- Jafek BW, Murrow B, Michaels R, Restrepo D, Linschoten M. Biopsies of human olfactory epithelium. *Chem Senses* 2002;27:623-628

Chapter 6

Kalmey JK, Thewissen JG, Dluzen DE. Age-related size reduction of foramina in the cribriform plate. *Anat Rec* 1998;251:326-329

Kobayashi K, Kumakura M, Yoshimura K, Shindo J. Stereo-structural study of the lingual papillae and their connective tissue cores in relation to ageing changes in the human tongue. *Ital J Anat Embryol* 2001;106:305-311

Koskinen S, Kalviainen N, Tuorila H. Perception of chemosensory stimuli and related responses to flavored yogurts in the young and elderly. *Food Qual Prefer* 2003a;14:623-635

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

Koskinen S, Tuorila H. Performance on an odor detection and identification test as a predictor of ortho- and retronasal odor intensity ratings in the young and elderly. *Food Qual Prefer* 2005;16:383-392

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

Kovacs T, Cairns NJ, Lantos PL. beta-amyloid deposition and neurofibrillary tangle formation in the olfactory bulb in ageing and Alzheimer's disease. *Neuropathol Appl Neurobiol* 1999;25:481-491

Krantz EM, Schubert CR, Dalton DS, Zhong W, Huang GH, Klein BE, Klein R, Nieto FJ, Cruickshanks KJ. Test-retest reliability of the San Diego Odor Identification Test and comparison with the brief smell identification test. *Chem Senses* 2009;34:435-440

Kremer S, Bult JH, Mojet J, Kroeze JH. Compensation for age-associated chemosensory losses and its effect on the pleasantness of a custard dessert and a tomato drink. *Appetite* 2007a;48:96-103

Kremer S, Bult JH, Mojet J, Kroeze JH. Food perception with age and its relationship to pleasantness. *Chem Senses* 2007b;32:591-602

Landis BN, Welge-Luessen A, Bramerson A, Bende M, Mueller CA, Nordin S, Hummel T. "Taste Strips" - a rapid, lateralized, gustatory bedside identification test based on impregnated filter papers. *J Neurol* 2009;256:242-248

Larsson M, Finkel D, Pedersen NL. Odor identification: influences of age, gender, cognition, and personality. *J Gerontol B Psychol Sci Soc Sci* 2000;55:P304-310

Laureati M, Pagliarini E, Calcinoni O, Bidoglio M. Sensory acceptability of traditional food preparations by elderly people. *Food Qual and Prefer* 2005;17:43-52

Le Floch JP, Bauduceau B, Levy M, Mosnier-Pudar H, Sachon C, Kakou B. Self-monitoring of blood glucose, cutaneous finger injury, and sensory loss in diabetic patients. *Diabetes Care* 2008;31:e73

Le Floch JP, Le Lievre G, Labroue M, Paul M, Peynegre R, Perlemuter L. Smell dysfunction and related factors in diabetic patients. *Diabetes Care* 1993;16:934-937

Le Floch JP, Le Lievre G, Sadoun J, Perlemuter L, Peynegre R, Hazard J. Taste impairment and related factors in type I diabetes mellitus. *Diabetes Care* 1989;12:173-178

Le Floch JP, Le Lievre G, Verroust J, Philippon C, Peynegre R, Perlemuter L. Factors related to the electric taste threshold in type 1 diabetic patients. *Diabet Med* 1990;7:526-531

Lehrer S, Levine E, Bloomer WD. Abnormally diminished sense of smell in women with oestrogen receptor positive breast cancer. *Lancet* 1985;2:333

- Linschoten MR, Harvey LO, Jr., Eller PM, Jafek BW. Fast and accurate measurement of taste and smell thresholds using a maximum-likelihood adaptive staircase procedure. *Percept Psychophys* 2001;63:1330-1347
- Loo AT, Youngentob SL, Kent PF, Schwob JE. The aging olfactory epithelium: neurogenesis, response to damage, and odorant-induced activity. *Int J Dev Neurosci* 1996;14:881-900
- Lötsch J, Lange C, Hummel T. A simple and reliable method for clinical assessment of odor thresholds. *Chem Senses* 2004;29:311-317
- Mak YE, Simmons KB, Gitelman DR, Small DM. Taste and olfactory intensity perception changes following left insular stroke. *Behav Neurosci* 2005;119:1693-1700
- Mathey MF, Siebelink E, de Graaf C, Van Staveren WA. Flavor enhancement of food improves dietary intake and nutritional status of elderly nursing home residents. *J Gerontol A Biol Sci Med Sci* 2001;56:M200-205
- Matsuda T, Doty RL. Regional taste sensitivity to NaCl: relationship to subject age, tongue locus and area of stimulation. *Chem Senses* 1995;20:283-290
- Mattes RD. Reliability of psychophysical measures of gustatory function. *Percept Psychophys* 1988;43:107-114
- Mavi A, Ceyhan O. Bitter taste threshold and its relation to number of circumvallate papillae in the elderly. *Aging (Milano)* 1999;11:61-63
- Meisami E, Mikhail L, Baim D, Bhatnagar KP. Human olfactory bulb: aging of glomeruli and mitral cells and a search for the accessory olfactory bulb. *Ann N Y Acad Sci* 1998;855:708-715
- Mela DJ. Why do we like what we like? *J Sci Food Agric* 2000;81:10-16
- Menashe I, Man O, Lancet D, Gilad Y. Different noses for different people. *Nat Genet* 2003;34:143-144
- Miller IJ, Jr. Human taste bud density across adult age groups. *J Gerontol* 1988;43:B26-30
- Miller IJ, Jr. Variation in human taste bud density as a function of age. *Ann N Y Acad Sci* 1989;561:307-319
- Miller IJ, Jr., Reedy FE, Jr. Variations in human taste bud density and taste intensity perception. *Physiol Behav* 1990;47:1213-1219
- Mistretta CM, Baum BJ. Quantitative study of taste buds in fungiform and circumvallate papillae of young and aged rats. *J Anat* 1984;138 (Pt 2):323-332
- Mojet J, Christ-Hazelhof E, Heidema J. Taste perception with age: pleasantness and its relationship with threshold sensitivity and supra-threshold intensity of five taste qualities. *Food Qual Prefer* 2005;16:413-423
- Mojet J, Heidema J, Christ-Hazelhof E. Taste perception with age: generic or specific losses in supra-threshold intensities of five taste qualities? *Chem Senses* 2003;28:397-413
- Moore PA, Guggenheimer J, Etzel KR, Weyant RJ, Orchard T. Type 1 diabetes mellitus, xerostomia, and salivary flow rates. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2001;92:281-291

Chapter 6

Mossman KL, Henkin RI. Radiation-induced changes in taste acuity in cancer patients. *Int J Radiat Oncol Biol Phys* 1978;4:663-670

Mueller C, Kallert S, Renner B, Stiassny K, Temmel AF, Hummel T, Kobal G. Quantitative assessment of gustatory function in a clinical context using impregnated "taste strips". *Rhinology* 2003;41:2-6

Mueller C, Renner B. A new procedure for the short screening of olfactory function using five items from the "Sniffin' Sticks" identification test kit. *Am J Rhinol* 2006;20:113-116

Mueller CA, Khatib S, Naka A, Temmel AF, Hummel T. Clinical assessment of gustatory function before and after middle ear surgery: a prospective study with a two-year follow-up period. *Ann Otol Rhinol Laryngol* 2008;117:769-773

Murphy C. Nutrition and chemosensory perception in the elderly. *Crit Rev Food Sci Nutr* 1993;33:3-15

Murphy C, Cerf-Ducastel B, Calhoun-Haney R, Gilbert PE, Ferdon S. ERP, fMRI and functional connectivity studies of brain response to odor in normal aging and Alzheimer's disease. *Chem Senses* 2005;30 Suppl 1:170-171

Murphy C, Schubert CR, Cruickshanks KJ, Klein BE, Klein R, Nondahl DM. Prevalence of olfactory impairment in older adults. *JAMA* 2002;288:2307-2312

Murray C, Solish N. Metallic taste: an unusual reaction to botulinum toxin A. *Dermatol Surg* 2003;29:562-563

Murray RC, Calof AL. Neuronal regeneration: lessons from the olfactory system. *Semin Cell Dev Biol* 1999;10:421-431

Nagler RM. Salivary glands and the aging process: mechanistic aspects, health-status and medicinal-efficacy monitoring. *Biogerontology* 2004;5:223-233

Nagler RM, Hershkovich O. Age-related changes in unstimulated salivary function and composition and its relations to medications and oral sensorial complaints. *Aging Clin Exp Res* 2005;17:358-366

Nalcaci R, Baran I. Factors associated with self-reported halitosis (SRH) and perceived taste disturbance (PTD) in elderly. *Arch Gerontol Geriatr* 2008;46:307-316

Nalcaci R, Erdemir EO, Baran I. Evaluation of the oral health status of the people aged 65 years and over living in near rural district of Middle Anatolia, Turkey. *Arch Gerontol Geriatr* 2007;45:55-64

Nicolaescu SA, Wertheimer JM, Barbash SE, Doty RL. Electrical taste thresholds established on the medial tongue using two sizes of electrodes. *Laryngoscope* 2005;115:1509-1511

Nijs KA, de Graaf C, Siebelink E, Blauw YH, Vanneste V, Kok FJ, van Staveren WA. Effect of family-style meals on energy intake and risk of malnutrition in dutch nursing home residents: a randomized controlled trial. *J Gerontol A Biol Sci Med Sci* 2006;61:935-942

Nordin S, Bramerson A, Bringlof E, Kobal G, Hummel T, Bende M. Substance and tongue-region specific loss in basic taste-quality identification in elderly adults. *Eur Arch Otorhinolaryngol* 2007;264:285-289

Ohno T, Uematsu H, Nozaki S, Sugimoto K. Improvement of taste sensitivity of the nursed elderly by oral care. *J Med Dent Sci* 2003;50:101-107

Ovesen L, Sorensen M, Hannibal J, Allingstrup L. Electrical taste detection thresholds and chemical smell detection thresholds in patients with cancer. *Cancer* 1991;68:2260-2265

- Paik SI, Lehman MN, Seiden AM, Duncan HJ, Smith DV. Human olfactory biopsy. The influence of age and receptor distribution. *Arch Otolaryngol Head Neck Surg* 1992;118:731-738
- Patton LL, Siegel MA, Benoliel R, De Laat A. Management of burning mouth syndrome: systematic review and management recommendations. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2007;103 Suppl:S39 e31-13
- Posner BM, Jette A, Smigelski C, Miller D, Mitchell P. Nutritional risk in New England elders. *J Gerontol* 1994;49:M123-132
- Potter H, Butters N. An assessment of olfactory deficits in patients with damage to prefrontal cortex. *Neuropsychologia* 1980;18:621-628
- Rhodes VA, McDaniel RW, Hanson B, Markway E, Johnson M. Sensory perception of patients on selected antineoplastic chemotherapy protocols. *Cancer Nurs* 1994;17:45-51
- Rolls BJ. Appetite, hunger, and satiety in the elderly. *Crit Rev Food Sci Nutr* 1993;33:39-44
- Sakagami M. Taste disturbance and its recovery after middle ear surgery. *Chem Senses* 2005;30(suppl 1):i220-i221
- Schiffman SS. Perception of taste and smell in elderly persons. *Crit Rev Food Sci Nutr* 1993;33:17-26
- Schiffman SS. Taste and smell losses in normal aging and disease. *JAMA* 1997;278:1357-1362
- Schiffman SS. Sensory enhancement of foods for the elderly with monosodium glutamate and flavors. *Food Rev Int* 1998;14:321-333
- Schiffman SS. Critical illness and changes in sensory perception. *Proc Nutr Soc* 2007;66:331-345
- Schiffman SS, Clark CM, Warwick ZS. Gustatory and olfactory dysfunction in dementia: not specific to Alzheimer's disease. *Neurobiol Aging* 1990;11:597-600
- Schiffman SS, Graham BG. Taste and smell perception affect appetite and immunity in the elderly. *Eur J Clin Nutr* 2000;54 Suppl 3:S54-63
- Schiffman SS, Moss J, Erickson RP. Thresholds of food odors in the elderly. *Exp Aging Res* 1976;2:389-398
- Schiffman SS, Zervakis J. Taste and smell perception in the elderly: effect of medications and disease. *Adv Food Nutr Res* 2002;44:247-346
- Scott J. Structural changes in salivary glands. *Front Oral Physiol* 1987;6:40-62
- Scott TR. Taste: the neural basis of body wisdom. *World Rev Nutr Diet* 1992;67:1-39
- Segovia C, Hutchinson I, Laing DG, Jinks AL. A quantitative study of fungiform papillae and taste pore density in adults and children. *Brain Res Dev Brain Res* 2002;138:135-146
- Seiberling KA, Conley DB. Aging and olfactory and taste function. *Otolaryngol Clin North Am* 2004;37:1209-1228, vii
- Sewards TV. Dual separate pathways for sensory and hedonic aspects of taste. *Brain Res Bull* 2004;62:271-283

Chapter 6

- Shimizu Y. A histomorphometric study of the age-related changes of the human taste buds in circumvallate papillae. *Oral Med Pathol* 1997;2:17-24
- Ship JA. The influence of aging on oral health and consequences for taste and smell. *Physiol Behav* 1999;66:209-215
- Ship JA, Baum BJ. Is reduced salivary flow normal in old people? *Lancet* 1990;336:1507
- Ship JA, Nolan NE, Puckett SA. Longitudinal analysis of parotid and submandibular salivary flow rates in healthy, different-aged adults. *J Gerontol A Biol Sci Med Sci* 1995;50:M285-289
- Sienkiewicz-Jarosz H, Scinska A, Kuran W, Ryglewicz D, Rogowski A, Wrobel E, Korkosz A, Kukwa A, Kostowski W, Bienkowski P. Taste responses in patients with Parkinson's disease. *J Neurol Neurosurg Psychiatry* 2005;76:40-46
- Smith DV. Taste intensity as a function of area and concentration: differentiation between compounds. *J Exp Psychol* 1971;87:163-171
- Smutzer G, Lam S, Hastings L, Desai H, Abarintos RA, Sobel M, Sayed N. A test for measuring gustatory function. *Laryngoscope* 2008;118:1411-1416
- Sone M, Sakagami M, Tsuji K, Mishiroy Y. Younger patients have a higher rate of recovery of taste function after middle ear surgery. *Arch Otolaryngol Head Neck Surg* 2001;127:967-969
- Stevens JC, Bartoshuk LM, Cain WS. Chemical senses and aging: taste versus smell. *Chem Sens* 1984;9:167-179
- Stillman JA, Morton RP, Hay KD, Ahmad Z, Goldsmith D. Electrogustometry: strengths, weaknesses, and clinical evidence of stimulus boundaries. *Clin Otolaryngol Allied Sci* 2003;28:406-410
- Suda S, Takagai S, Inoshima-Takahashi K, Sugihara G, Mori N, Takei N. Electroconvulsive therapy for burning mouth syndrome. *Acta Psychiatr Scand* 2008;118:503-504
- Suzuki Y, Critchley HD, Suckling J, Fukuda R, Williams SC, Andrew C, Howard R, Ouldred E, Bryant C, Swift CG, Jackson SH. Functional magnetic resonance imaging of odor identification: the effect of aging. *J Gerontol A Biol Sci Med Sci* 2001;56:M756-760
- Temmel AF, Pabinger S, Quint C, Munda P, Ferenci P, Hummel T. Dysfunction of the liver affects the sense of smell. *Wien Klin Wochenschr* 2005;117:26-30
- Thomas-Danguin T, Rouby C, Sicard G, Vigouroux M, Farget V, Johanson A, Bengtson A, Hall G, Ormel W, De Graaf C, Rousseau F, Dumont JP. Development of the ETOC: a European test of olfactory capabilities. *Rhinology* 2003;41:142-151
- Toledano A, Gonzalez E, Rodriguez G, Galindo N. The validity of CCCRC test in patients with nasal polyposis. *Rhinology* 2007;45:54-58
- Tylenda CA, Ship JA, Fox PC, Baum BJ. Evaluation of submandibular salivary flow rate in different age groups. *J Dent Res* 1988;67:1225-1228
- Vissink A, Spijkervet FK, Van Nieuw Amerongen A. Aging and saliva: a review of the literature. *Spec Care Dentist* 1996;16:95-103
- Wang H, Zhou M, Brand J, Huang L. Inflammation activates the interferon signaling pathways in taste bud cells. *J Neurosci* 2007;27:10703-10713

- Wang J, Eslinger PJ, Smith MB, Yang QX. Functional magnetic resonance imaging study of human olfaction and normal aging. *J Gerontol A Biol Sci Med Sci* 2005;60:510-514
- Waterhouse JP, Chisholm DM, Winter RB, Patel M, Yale RS. Replacement of functional parenchymal cells by fat and connective tissue in human submandibular salivary glands: an age-related change. *J Oral Pathol* 1973;2:16-27
- Wayler AH, Perlmutter LC, Cardello AV, Jones JA, Chauncey HH. Effects of age and removable artificial dentition on taste. *Spec Care Dentist* 1990;10:107-113
- Weiffenbach JM, Bartoshuk LM. Taste and smell. *Clin Geriatr Med* 1992;8:543-555
- Weiffenbach JM, Fox PC, Baum BJ. Taste and salivary function. *Proc Natl Acad Sci U S A* 1986;83:6103-6106
- Wilson MM, Thomas DR, Rubenstein LZ, Chibnall JT, Anderson S, Baxi A, Diebold MR, Morley JE. Appetite assessment: simple appetite questionnaire predicts weight loss in community-dwelling adults and nursing home residents. *Am J Clin Nutr* 2005;82:1074-1081
- Wrobel BB, Leopold DA. Clinical assessment of patients with smell and taste disorders. *Otolaryngol Clin North Am* 2004;37:1127-1142
- Wu AJ, Atkinson JC, Fox PC, Baum BJ, Ship JA. Cross-sectional and longitudinal analyses of stimulated parotid salivary constituents in healthy, different-aged subjects. *J Gerontol* 1993;48:M219-224
- Yamagishi M, Takami S, Getchell TV. Innervation in human taste buds and its decrease in Alzheimer's disease patients. *Acta Otolaryngol* 1995;115:678-684
- Yamamoto T, Shibata M, Goto N, Ezure H, Ito J, Suzuki M. Morphometric evaluation of the human tractus solitarius. *Okajimas Folia Anat Jpn* 2005;82:5-8
- Yousem DM, Geckle RJ, Bilker WB, Doty RL. Olfactory bulb and tract and temporal lobe volumes. Normative data across decades. *Ann N Y Acad Sci* 1998;855:546-555
- Yousem DM, Geckle RJ, Bilker WB, McKeown DA, Doty RL. Posttraumatic olfactory dysfunction: MR and clinical evaluation. *AJNR Am J Neuroradiol* 1996;17:1171-1179
- Zandstra EH, de Graaf C, Van Trijp HCM, Van Staveren WA. Laboratory hedonic rating as predictor of consumption: Three brief-exposure tests compared to an ad libitum consumption test. *Food Qual Preference* 1999;10:411-418
- Zhang GH, Zhang HY, Wang XF, Zhan YH, Deng SP, Qin YM. The relationship between fungiform papillae density and detection threshold for sucrose in the young males. *Chem Senses* 2009;34:93-99

SUMMARY

Motivation for the study

The world's elderly population aged 65 and older is growing and simultaneously these elderly also tend to grow older. It is estimated that by the year 2030, the percentage of elderly will be up to two times as high. With increasing age, there is a decline in food intake that may be accompanied by weight loss in many elderly and the latter serves a marker of risk of mortality. It is often speculated that the age related decline in taste and in particular smell performance can add to the decreased food intake by causing a change in liking of food. Aging is also accompanied by a reduced dietary variety, which could add to dietary inadequacies. The reduced variety may be partly explained by a decreased sensitivity for boredom after repeated monotonous exposure to foods. However, whether the lower sensitivity occurs with all food products under all circumstances is not clear.

On average elderly people prefer higher taste and/or odor concentrations in certain solutions and food products and it has been suggested that flavor enhancement (by adding a taste and/or an odor to enhance or intensify the flavor of the food) may counteract for the diminished taste and smell performance in order to increase liking and subsequently intake among elderly people. This idea served as one of the basic hypotheses of this thesis.

In reality there is little direct evidence that links a flavor enhancement treatment to an impaired taste and smell functioning and studies in this field found either no or mixed results. Furthermore, regarding flavor enhancement as an approach to increase intake in order to treat and prevent undernutrition, the effect of a short-term flavor enhancement treatment on intake is not pronounced whereas the long-term approach does point out its potential to increase the intake of flavor-enhanced foods. Because of these inconsistencies, verification of the effect of flavor enhancement or higher stimulus concentrations on liking and/or intake and its assumed compensatory action was appropriate. The aim in this thesis was to study the effect of flavor enhancement with MSG and/or other flavors on liking and/or food intake in elderly people and the relationship between an impaired taste and smell performance and the liking of flavor-enhanced foods.

Field studies

When flavor enhancement of foods is used as an instrument to stimulate food and nutrient intake, it is important to know how elderly will respond to a daily repeated exposure to particular foods. We investigated the effect of repeated exposure to fruit drinks on the intake, pleasantness and boredom in young and non-institutionalized

elderly adults (**chapter 2**). The aim was to determine whether elderly would be sensitive to boredom if daily ad libitum consumption were encouraged of several fruit drinks with varying sweetness levels in a real life setting. Young and elderly women participated in a randomized within subjects cross over trial with three intervention periods of 12 days and received 1 L of one type of drink per day. Results show that for the elderly women, mean consumption increased but pleasantness and boredom were stable. In addition, the elderly preferred the fruit drink with the highest sugar content the most. For the young women the mean consumption and pleasantness decreased and boredom increased. Thus, the elderly experienced no increased boredom. This study supports the decrease in sensitivity to boredom after repeated exposure as found by others.

Our next question was, if flavor enhancement of foods can compensate for an impaired chemosensory performance in elderly people. In theory, higher flavor concentrations are needed in order to correct for the lower taste and smell perception in order to obtain a similar optimal perceived intensity. However, there is little direct evidence that links an impaired taste and smell functioning to a higher liking and/or intake of flavor-enhanced foods. To study this relationship, 120 free-living older adults participated in a single blind randomized within subject cross over trial and were divided over 4 groups based on the assessed gustatory and olfactory functioning (**chapter 3**). Subjects received a flavor-enhanced tomato soup (1200 mg/L MSG (0.12% MSG) + 3 g/L celery powder) and a non-enhanced version and intake and liking were assessed. The results showed that both intake and liking of the flavor-enhanced soup was neither increased within the group of elderly with low taste and smell sensitivity, nor in any of the other groups, and thus no relationship was established. This study does not support the assumption that flavor enhancement counteracts for the diminished taste and/or smell performance.

The next question we wanted to answer was whether or not a long-term consumption of flavor-enhanced foods would lead to an increased food intake and a change in body weight. Therefore, the study described in **chapter 4** aimed to determine if daily addition of 700 mg flavor and/or 300 mg monosodium glutamate (MSG) to the animal protein part of the cooked meal for 16 weeks leads to an increase in energy intake and in body weight in nursing home elderly. This was a single blind randomized 16 weeks parallel study consisting of a control group (n=23), a MSG group (n=19), a flavor group (n=19) and a flavor plus MSG group (n=22). We measured intake and body weight before and at the end of the intervention period. Energy intake and body weight did not increase within any of the four groups. Also between the groups, no differences were found in changes in energy intake and body weight. We concluded

Summary

that enhancing the taste of a cooked meal with flavor and/or MSG does not lead to a higher energy intake and body weight among nursing home elderly. Thus, our findings do not support the results found by others on flavor enhancement as a way to increase food intake.

As a result of our negative findings in the two previous studies (**chapters 3 and 4**) and because the optimal preferred amount of MSG differs between food items, we decided to first obtain an optimal preferred concentration of MSG in mashed potatoes, spinach and ground beef (sensory study) and then study its effect on intake among institutionalized elderly (intake study) (**chapter 5**). We found an optimal preferred amount of MSG (0.5%) in mashed potatoes using a MSG range varying from 0.5%-2% but not for spinach and ground beef, possibly because of their complex taste. To study the effect on intake we had a single blind within subject cross over design and used the 0.5% MSG in mashed potatoes and 2% in both spinach and ground beef. Our results showed that intake was not different between the foods with and without MSG or the total meal and we concluded that 0.5% MSG and 2% MSG does not guarantee a higher intake among elderly. Again, our findings did not support the effect of flavor enhancement on intake as found by others. We believe that because of the chemosensory heterogeneity of the elderly population a more individual flavor enhancement may be required to improve the dietary intake and the sensory experience.

Reflection and future strategies

In the final chapter of this thesis (general discussion, **chapter 6**) we first described the main findings of our studies and reflected on our hypothesis that flavor enhancement may improve liking and/or intake by making up for the decline in taste and smell performance in elderly people. Clearly, our findings did not support the associations in this hypothesis and perhaps these associations are more complex as previously assumed. Our recent finding that liking remains fairly stable may also contribute to these negative results. Furthermore, regarding the association between liking and intake, it may be hypothesized that upon aging the influence of environmental and social factors become more important for food intake than internal factors such as hunger, satiety and thirst, although palatability remains important. This implies that these factors should be taken into account to address the decline in intake.

We proceed in this chapter with a rationale for a more individual tailored flavor enhancement of foods to improve the dietary intake and the sensory experience of the elderly population. First, we examined into depth, the major physiological causes

upon aging that affect taste and smell performance such as diseases, treatments, certain medication, environmental exposure (in case of smell perception) and the process of aging itself (to some extent). This resulted in more insight in the heterogeneity of chemosensory perception in elderly. Based on these results we differentiated the elderly into 3 groups the 'normal' group with equal chemosensory performance as young people, the 'low' group with hypogeusia (diminished taste perception) and/or hyposmia (diminished olfactory perception) and the 'zero' group with ageusia and/or anosmia with no taste and/or smell perception.

One possible cause for not finding any associations between an impaired chemosensory performance in elderly and an increased liking/intake for flavor-enhanced foods is that we lack the measurement instruments to reliably assess sensory performance. Therefore, we discussed the reliability and feasibility of several tests for the assessment of performance measures such as changes in detection threshold, identification ability, supra threshold sensitivity and/or preference. It was concluded that we have the appropriate performance measures, so that the lack of associations cannot be attributed to unreliable measurements. These test or methods are also needed to assess the taste and smell perception of the elderly individual after which adequate treatment of the taste or smell dysfunction may follow.

Thirdly, we proposed a future strategy of flavor enhancement of food as part of the treatment and prevention of undernutrition of elderly in which the emphasis is on the characterization of those elderly that have an indication of a low food intake and a diminished taste and smell functioning.

In conclusion, we cannot accept our hypothesis that standardized flavor enhancement of foods is an effective approach to increase food intake in frail elderly people. The fact that elderly are a heterogeneous group with various degrees of taste and smell loss and can be characterized as such, suggests a more individual, tailored taste and/or flavor enhancement of foods as part of a treatment or prevention of undernutrition. We have embedded this suggestion in a proposed future strategy for flavor enhancement of foods.

SAMENVATTING

Motivatie voor de studie

De populatie oudere mensen (≥ 65 jaar) op wereldniveau groeit en tegelijkertijd blijken deze ouderen ook langer te leven. Men schat dat tegen het jaar 2030, het percentage mensen boven de 65 jaar tot twee keer zo hoog zal zijn dan in 2000. Met de toenemende leeftijd daalt bij veel ouderen de voedselinname en dat gaat dikwijls samen met gewichtsverlies. Gewichtsverlies is een risicofactor voor sterfte. Men denkt vaak dat de aan leeftijd verwante daling in smaak- en in het bijzonder reukvermogen kan bijdragen aan een lagere voedselinname door een verandering te veroorzaken in de aangenaamheid van voedsel. Dit proces gaat vaak gepaard met een minder gevarieerd voedselpatroon dat op den duur kan leiden tot inadequate voeding. De daling in variatie kan gedeeltelijk worden verklaard door een mindere gevoeligheid voor verveling na herhaalde monotone blootstelling aan voedsel. Het is nog niet duidelijk of de afname in gevoeligheid voor verveling zich voordoet bij alle voedingsmiddelen en onder alle omstandigheden.

Ouderen hebben gemiddeld een voorkeur voor een hogere smaak- en/of geurconcentraties in bepaalde oplossingen en voedingsmiddelen. Het toevoegen van een smaak en/of geur aan voedsel zou de smaak van het eten versterken en zodoende de aangenaamheid en de hoeveelheid voedselinname van ouderen tijdens de maaltijd verhogen. Deze stelling diende als uitgangspunt voor dit proefschrift.

In de literatuur was er weinig direct bewijs dat de positieve effecten van smaakversterking gerelateerd zijn aan een verminderd smaak- en reukvermogen. De onderzoeken op dit gebied vinden geen of controversiële resultaten. Smaakversterking als methode om ondervoeding te behandelen en te voorkomen, heeft op korte termijn weinig effect terwijl smaakversterking op de lange termijn mogelijk wel de inname van voedsel verhoogt. Vanwege de inconsistente resultaten is het van belang het effect van smaakversterking op de aangenaamheid en/of inname van voedsel en de veronderstelde compensatoire werking nauwkeurig te onderzoeken. Het doel van dit proefschrift was het onderzoeken van het effect van smaakversterking met MSG en/of aroma's op de waardering en/of voedselinname van oudere mensen. Daarnaast is de relatie tussen een verminderd smaak- en reukvermogen en de aangenaamheid van voedsel met smaakversterkers onderzocht.

De studies

Wanneer smaakversterking als methode wordt gebruikt om de voedselinname te bevorderen, is het belangrijk om te weten hoe ouderen reageren op een dagelijks herhaalde blootstelling aan bepaalde voedingsmiddelen. Wij onderzochten daarom het effect van herhaalde blootstelling aan fruitdranken op de inname, de aangenaamheid en de verveling bij jonge volwassenen en onder thuis wonende (niet-geïnstitutionaliseerde) ouderen (**Hoofdstuk 2**). Het doel was te bepalen of ouderen gevoelig zouden zijn voor verveling als ze dagelijks net zoveel konden drinken als ze wilden van 3 fruitdranken die varieerden in zoetheid. De studie is uitgevoerd in de dagelijkse thuissituatie van consumenten en niet in een laboratorium. Jonge en oudere vrouwen namen deel aan dit onderzoek waarbij iedere deelnemer willekeurig 1 liter van een bepaalde drank per dag kreeg gedurende 12 dagen. Tussen de 3 interventieperiodes van 12 dagen was er een wash-out periode van 2 dagen. De resultaten laten zien dat onder de oudere vrouwen, de gemiddelde consumptie steeg maar de aangenaamheid en de verveling bleven stabiel. Bovendien prefereerden de ouderen de fruitdrank met het hoogste zoetgehalte. Onder de jongere vrouwen daalde de gemiddelde consumptie en aangenaamheid en nam de verveling toe. Samenvattend nam de verveling onder de ouderen niet toe en de daling in gevoeligheid voor verveling na herhaalde blootstelling komt overeen met de resultaten van eerdere studies.

Onze volgende vraag was of smaakversterking kan compenseren voor een verminderd smaak- en reukvermogen onder oudere mensen. Theoretisch zijn er hogere smaak- en geurstoffenconcentraties nodig om de vermindering in smaak- en reukvermogen op te heffen, zodat een gelijkwaardige optimale intensiteit kan worden waargenomen. Toch is er weinig bewijs voor een relatie tussen een verminderd smaak- en reukvermogen en het aangenamer vinden en/of meer eten van voedsel dat in smaak is versterkt. Om dit verband te bestuderen, namen 120 niet-geïnstitutionaliseerde ouderen deel aan een onderzoek en werden op basis van hun smaak- en reukvermogen, willekeurig verdeeld over 4 groepen (**Hoofdstuk 3**). Het onderzoek werd enkelblind uitgevoerd. De proefpersonen kregen zowel een in smaak versterkte tomatensoep als een niet versterkte tomatensoep aangeboden die ze beiden beoordeelden op aangenaamheid. Ook werd er onderzocht hoeveel ze aten van de beiden soepen. De resultaten wezen uit dat noch de aangenaamheid noch de consumptie toenam binnen de groep ouderen met een verminderd smaak- en reukvermogen. Wij vonden hetzelfde resultaat in de overige drie groepen en daarmee werd er geen verband gevonden tussen een verminderd smaak- en reukvermogen en het aangenamer vinden en/of meer eten van voedsel dat in smaak

Samenvatting

is versterkt. Deze studie heeft niet uitgewezen dat smaakversterking kan compenseren voor een verminderd smaak- en reukvermogen.

Binnen de volgende onderzoeksvraag werd onderzocht of op de lange termijn, smaakversterking door middel van het toevoegen van 700 mg aroma en/of 300 mg mono sodium glutamaat (MSG) aan het dierlijke eiwitdeel van een warme maaltijd zou leiden tot een verhoogde voedselinname en lichaamsgewicht onder ouderen in een verzorgingshuis (**Hoofdstuk 4**). De ouderen werden willekeurig verdeeld over 4 groepen die parallel aan elkaar werden onderzocht, namelijk een controle groep (n=23), een MSG groep (n=19), een aroma groep (n=19) en een aroma plus MSG groep (n=22). Dit enkelblinde onderzoek duurde 16 weken. De voedselinname en lichaamsgewicht werden gemeten vóór en aan het eind van de interventie. De resultaten laten zien dat de energie-inname en het lichaamsgewicht niet toenamen binnen de 4 groepen. Ook werd geen verschil gevonden tussen de 4 groepen met betrekking tot energie-inname en gewicht. We concluderen dat het versterken van de smaak van een warme maaltijd met aroma's en MSG niet leidt tot een hogere energie-inname en lichaamsgewicht onder ouderen in een verzorgingshuis.

Naar aanleiding van onze nul resultaten zoals beschreven in **Hoofdstukken 3 en 4** en omdat de optimaal geprefereerde hoeveelheid MSG verschilt tussen voedingsmiddelen, besloten we deze optimale preferentie eerst te bepalen voor aardappelpuree, spinazie en gehakt (sensorische studie). Vervolgens onderzochten we het effect van deze producten met een optimaal geprefereerde hoeveelheid MSG op de inname (inname studie) (**Hoofdstuk 5**). Binnen een range van 0.5-2% MSG, vonden we een optimaal geprefereerde hoeveelheid van 0.5% MSG voor aardappelpuree. Dit werd echter niet gevonden voor spinazie en gehakt, waarschijnlijk door hun complexe smaak. Om het effect op de inname te onderzoeken, hebben we 0.5% MSG toegevoegd aan aardappelpuree en 2% MSG aan zowel spinazie als gehakt. Deze studie werd enkelblind uitgevoerd. Onze resultaten wezen uit dat er geen verschil was in inname tussen de producten met en zonder MSG en dit gold ook voor de hele maaltijd. Wij concludeerden dat toevoeging van 0.5% MG en 2% MSG geen hogere inname garandeert onder ouderen. Vanwege de heterogeniteit in smaak- en reukvermogen binnen de populatie ouderen, denken wij dat smaakversterking van voedsel mogelijk meer op het individu aangepast dient te worden om zo de voedselinname en de sensorische beleving te verbeteren.

Overdenking en toekomstige strategieën

In de algemene discussie (**Hoofdstuk 6**) worden de belangrijkste bevindingen van onze onderzoeken beschrijven en reflecteren we op onze hypothese dat smaakversterking de aangenaamheid en/of voedselinname kan doen toenemen door te compenseren voor een verminderd smaak- en reukvermogen onder oudere

mensen. Het is duidelijk dat de gevonden resultaten de hypothese niet bevestigen en wellicht zijn de verbanden binnen de gestelde hypothese ingewikkelder dan eerder verondersteld. Onze recente bevinding dat de aangenaamheid vrij stabiel blijft kan ook hebben bijgedragen aan deze resultaten. Wat betreft de relatie tussen aangenaamheid en inname kan er gesteld worden dat door het ouder worden, de invloed van omgevingsfactoren en sociale factoren op de voedselinname belangrijker wordt dan de invloed van interne factoren zoals honger, verzadiging en dorst ook al blijft de factor aangenaamheid belangrijk. Hiermee dienen wij rekening te houden om de daling in voedselinname tegen te gaan.

Verder in de discussie voeren we een argument aan voor een meer individueel, op maat gesneden aanpak voor het toevoegen van smaakversterkers aan voedingsmiddelen om zo de inname en de sensorische beleving te verhogen. Eerst hebben we uitvoerig gekeken naar de belangrijkste fysiologische oorzaken die van invloed zijn op het smaak- en reukvermogen tijdens het ouder worden zoals ziektes, behandelingen, bepaalde medicatie, omgevingsfactoren (in geval van reukvermogen) en het verouderingsproces zelf. Dit gaf ons meer inzicht in de heterogeniteit in smaak- en reukwaarneming onder de ouderen. Gebaseerd op deze bevindingen kunnen we de ouderen in 3 groepen verdelen, namelijk de 'normale' groep met een smaak- en reukvermogen die gelijk is aan jongeren, de 'lage' groep met een verminderd smaak- en reukwaarneming en de 'nul' groep die niets kan proeven of ruiken.

De volgende vraag is of wij de sensorische gevoeligheid van jongeren en ouderen voldoende nauwkeurig kunnen vaststellen om verschillen aan te kunnen tonen. Daarom zijn de betrouwbaarheid en de haalbaarheid van verscheidene testen die veranderingen kunnen meten in de detectie drempel, identificatie vermogen, de gevoeligheid op bovendrempelniveau en de aangenaamheid bediscussieerd. Op basis van dit literatuuroverzicht kan worden geconcludeerd dat we wel de aangewezen meetinstrumenten hebben die verschillen in gevoeligheid kunnen vaststellen. Het feit dat wij geen verband vinden ligt dus niet aan onbetrouwbare meetmethodes. Deze methodes zijn ook nodig om de smaak- en geurwaarneming te bepalen van de ouderen om zo een adequate behandeling te bieden voor de vermindering in smaak en geur.

Tot slot wordt een toekomst strategie voorgesteld om met smaakversterking van voedsel ondervoeding te behandelen en te voorkomen bij die ouderen met een indicatie voor een lage voedselinname en een verminderd smaak- en reukvermogen.

Samenvatting

Samenvattend kunnen we niet bevestigen dat een standaard smaakversterking van voedsel een effectieve methode zou zijn om de voedselinname te verhogen van fragiele oudere mensen. Het feit dat ouderen een heterogene groep vormen met diverse gradaties in smaak en geurverlies en als dusdanig kunnen worden gekenmerkt, suggereert een meer aan het individu aangepaste aanpak van smaak- en/of aromaversterking om zo ondervoeding te behandelen of te voorkomen. Deze suggestie is verwerkt in een toekomstige strategie voor smaakversterking van voedingsmiddelen.

DANKWOORD

Net zoals het in het leven soms anders kan lopen dan voorgesteld, is dat ook het geval in het wetenschappelijk onderzoek. Een effect van verrijking heb ik niet gevonden, maar ik heb het *door* dit onderzoek wel mogen ervaren, bijzonder! Hieraan hebben diverse mensen bijgedragen, elk op een verschillende manier die ik op deze plaats hartelijk wil bedanken!

Allereerst mijn begeleiders. Kees, ik ben blij dat jij mij indertijd gevraagd hebt om dit onderzoek uit te voeren. Vanaf 2003 werd ik een onderzoeker op afstand toen ik met mijn gezin naar Amerika verhuisde, maar jouw begeleiding was er absoluut niet minder om. Je bent een fijne begeleider geweest en wist mij op de juiste manier te stimuleren. Dank je wel voor de vele gesprekken via de telefoon, voor het feit dat je tijd vrijmaakte als ik naar Nederland kwam om samen te werken –hoe druk je het ook had, voor jouw interesse in ons leven in Amerika, en in het bijzonder voor jouw bezoeken naar mij zodat we flink konden doorwerken. Ik heb het ontzettend gewaardeerd! Wya, dank je wel voor je begeleiding, dat je telkens naar Kees kwam voor de telefonische gesprekken, je doortastendheid, het duidelijk voor ogen houden van het doel op de momenten als ik dat wat minder had, de bijna dagelijkse telefoontjes van afgelopen zomer, en je snelle reactie op mijn geschreven stukken. Je begeleiding was zeer waardevol. Frans, dank je wel voor de gesprekken die altijd ingelast konden worden als ik maar voor een paar dagen in Nederland was en voor het in de gaten houden van de grote lijnen.

Iedereen die heeft geholpen met de onderzoeken. Wieke, ik wil je bedanken voor het uitdenken, opzetten en uitvoeren van de sapstudie. Gertrude, dank je wel voor jouw bijdrage aan de sapstudie in de vorm van een afstudeervak en ook voor het feit dat ik de afgelopen tijd bij jou terecht kon met praktische vragen. Jullie beiden, dank voor het leuke contact! Suzanne, Patty en Martine, als studenten onderzochten jullie elk een andere onderzoeksvraag en hebben jullie vol enthousiasme een enorme bijdrage geleverd aan dit proefschrift. Allen hartelijk dank hiervoor! Gerda, erg bedankt voor je inzet bij het soeponderzoek. Jacqueline, ik had mij geen betere collega kunnen voorstellen om samen het SMAAKVOL onderzoek mee op te zetten en uit te voeren. Rene was in die periode al naar Amerika vertrokken en Jean-Luc en ik bleven achter. Mede dankzij jou, werd het een fantastisch jaar! Dank je wel voor alles, en in het bijzonder dat je straks naast mij staat als mijn paranimf. Annuska, Marieke en Els hartelijk dank voor jullie hulp met het SMAAKVOL onderzoek.

Alle andere betrokkenen bij de onderzoeken. Olivier Kapetanacos (voormalig Quest Intl.) voor het beschikbaar stellen van MSG en de aroma's en Unilever Bestfoods

Dankwoord

voor de tomaten soep en de selderij poeder. Beiden erg bedankt! Jos Mojet, dank je wel voor je tijd en je feedback tijdens een last-minute bespreking. Gabriëlle van den Broek, bedankt voor het kopiëren en het inleveren van de leesversie. Zonder deelnemers was dit alles niet gelukt, dank je wel voor jullie tijd!

Tijdens dit promotie onderzoek ben ik een aantal keer op werkbezoek naar Nederland gekomen en het was elke keer fijn om iedereen weer te zien op de vakgroep. Riekie, Eric, Monica, Andrea, Annet, Rosalie, Lidwien, Ingeborg, Jan, Ypie, Lisette, Karin, Els, Saskia, Alida, Gertrude, Jill, Ondine en Marie, dank jullie wel voor al de gezellige momenten! Ook de collega's vóór mijn vertrek naar Amerika: Kristel, Rosalie, Marleen, Judith, Kim, Petra en Gie, bedankt voor de leuke tijd.

Alle vrienden in Nederland, Amerika, Frankrijk, Noorwegen en Singapore. Lieve Myrna en Serno, heel veel dank voor jullie steun door de jaren heen en opvang van Lois tijdens een van mijn werkbezoeken naar Nederland. Dat was een hele geruststelling. Maud, Ton, Anne-Greet, Sharda, Cees en Marjolein, Tessa, Leonie, bedankt voor jullie belangstelling. Ik hoop jullie straks weer te zien. Dear Ellen Sutton and Sherill Read, thank you both so much for all your prayers regarding my research. How I wish to see you both in the Netherlands. Michael Chang, thank you so much for the cover of this thesis. Linda, Chris and Lin, Chris and Robin, John and Julia, Oscar and Julie, I appreciate your friendship and your support. Sakia en Radboud, wat ben ik blij dat ik jullie heb ontmoet in Deerfield (USA). Radboud, heel erg bedankt voor al je hulp en in het bijzonder met betrekking tot de lay-out. Saskia, wat fijn dat je op Lois wilde passen zodat ik door kon werken. Dank je wel! Helene en Peter, bedankt voor jullie interesse en de nodige ontspanning. To new friends and new beginnings! Gerrit Vreeman (Purac USA), ook u bedankt voor u belangstelling. Ik heb het erg gewaardeerd. In Frankrijk, mijn studievriendin van het eerste moment! Marit, dank je wel voor je interesse! Dan zijn we nu aangekomen in Noorwegen, bij Simone en Stefan. Simone, onze vriendschap is vanaf het moment dat we een kamer deelden in het John Snow gebouw door de jaren heen alleen maar hechter geworden. Wat fijn dat jij straks naast mij staat als paranimf. Siem, dank je wel voor alles en in het bijzonder je aanstekelijke doorzettingsvermogen, je vele telefoontjes en je bereidheid om altijd te helpen –dit laatste geldt ook voor Stefan! And last but not least, Judith en Frederik. Helaas wonen we niet meer 13 min van elkaar vandaan maar eerder 13 uur. Judith, mijn buddy! Ik mis je en ik wil je bedanken voor al je steun in de vorm van gebeden maar ook in de vorm van het opvangen van Jean-Luc als ik naar Nederland ging en Rene moest werken. Dank je lieverd! Frederik, jij bedankt voor je niet aflatende interesse in mijn onderzoek. Tot gauw in Singapore!

Tot slot mijn familie. Lieve mama en papa, jullie hebben het onmogelijke gedaan: 5 weken voor een baby en een mondige 9-jarige gezorgd zodat ik kon doorwerken. Mijn dank is ZEER GROOT! Mijn schoonmoeder wil ik bedanken voor alle goede zorgen als ik weer naar Nederland kwam om te werken. Ik heb dit erg gewaardeerd. Philomena, dank je wel voor je interesse en voor je steun. Jouw telefoontjes –met aanmoedigingen- kwamen altijd op het juiste moment. Ook mijn broers Ralf, Remko, Mispa en schoonzus Lisette wil ik bedanken voor de fijne band die wij met elkaar hebben. Lieve Rene, ik ben zo blij met ons gezin. Dank je wel voor je al je steun door de jaren heen. Ik weet het, het heeft lang geduurd. Als laatste, mijn lieve Here God. Door dit onderzoek heb ik geleerd dat ik over niets bezorgd hoeft te zijn maar alleen U te vragen wat ik nodig heb en U te danken in mijn gebeden. Hierdoor heb ik Uw vrede mogen ervaren, en dat is mijn persoonlijke geestelijke verrijking.

Iedereen, hartelijk bedankt!

Natasja

ABOUT THE AUTHOR

Natasja Helenska Essed (July, 1971) was born in Nijmegen, The Netherlands. She passed secondary school, VWO at Colegio Arubano in Oranjestad (Aruba) in 1990. In that same year she returned to the Netherlands and started her study 'Human Nutrition' at Wageningen Agricultural University. During her study she worked for six months at the department of Human Nutrition at the University of Otago in Dunedin, New Zealand. In 1996 she earned her MSc degree in Human Nutrition with main topics in human nutrition and food science. From 1996-1997 she worked at the Department of Human Nutrition (Wageningen University) to help organize the conference 'Bioavailability'. She worked as a nutritionist for PreCon NL (1997-1999), Centrum voor Smaakonderzoek (1990-2000) and returned to the Department of Human Nutrition at Wageningen University to teach and organize several classes (2000-2001). In 2001 she was appointed as a PhD student and started the research, which resulted in this thesis. She presented parts of the results described in this thesis at the 10th Food Choice Conference in Wageningen, The Netherlands, June 30 - July 3, 2002 and at the European Sensory Network (ESN) Conference, in Porto, Portugal, May 8 and 9, 2007.

Natasja is married to Rene Monderen en they have two children, Jean-Luc and Lois. Since 2003, they reside in Deerfield, Illinois, USA.

This work was performed with financial support from the European Commission Quality of Life and Management of Living Recourses Fifth Framework Programme. QLK1-CT-1999-0001. Additional support was obtained from the International Technical Glutamate Committee.

The author gratefully acknowledges financial support for the printing of this thesis from Wageningen University and Ajinomoto.

Cover design: Michael Chang
Printing: Gildeprint Drukkerijen BV

Copyright © Natasja H Essed, 2009

