Helsingin yliopisto
Elintarviketeknologian laitos

University of Helsinki
Department of Food Technology

EKT-sarja 1313
EKT-series 1313

TEXTURE MODIFICATIONS IN SEMISOLID AND SOLID FOODS: SENSORY CHARACTERIZATION AND ACCEPTANCE IN DIFFERENT AGE GROUPS

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ACADEMIC DISSERTATION

To be presented, with the permission of the Faculty of Agriculture and Forestry, University of Helsinki, for public criticism in lecture hall B2, Viikki on August 8th 2002, at 12 noon

Helsinki 2002

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ISBN 952-10-0609-9 (print)
ISBN 952-10-0610-2 (pdf)
ISSN 0355-1180

Yliopistopaino
Helsinki 2002

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Kälviäinen, N. 2002. Texture modifications in semisolid and solid foods: sensory characterization and acceptance in different age groups. EKT series 1313. University of Helsinki, Department of Food Technology

ABSTRACT

Texture and flavor properties of semisolid and solid food products were studied using three food materials: high-viscosity gel samples, muesli oat flakes, and a fermented yogurt-like oat-bran product. Texture and flavor of these food products were modified by changing food components or processing parameters. The texture of the high-viscosity gel samples was modified using different thickeners (pectin, gelatin, starch, and a combination of gelatin and starch) and two concentrations of strawberry aroma. The texture and flavor of the muesli oat flakes were changed using processing conditions, e.g. two heat treatments and three thickness levels. Fermented oat brand products were modified on their texture (cooked oat seeds added vs. no seed addition), taste (two sucrose concentrations), and aroma (two orange aroma concentrations). The aim was to study how these changes affected sample texture and flavor properties. In addition, the effect of these changes on consumer preference was investigated. The effects of aging and previous experience on consumer texture and flavor preferences were also examined.

Trained sensory panels were used to study the effect of texture and flavor modifications on food attributes, like on texture, taste, odor, and flavor attributes. Different consumer age groups, from teen-agers to elderly, were used to study the effect of the changes on hedonic quality of the products. In addition, the effect of age and food attributes on consumers' preference evaluations, and the relative importance of food attributes were studied. A total of 407 consumers took part in the studies.

Modifications of food components and processing conditions produced both texture and flavor changes in the products. Each thickener used in high viscosity gel samples produced its own characteristic texture with its own characteristic flavor release properties. In the case of processing conditions, thickness levels had strong effects on muesli oat flake texture. The effect of heat treatments on texture was less intense but the high heat treatment produced

sweeter flakes than the mild heat treatment. The relative importance of food attributes depended on the food product. In the case of the fermented oat-bran product, flavor was the most important attribute predicting consumer preferences, whereas for high-viscosity gel samples and muesli oat flakes, texture exceeded flavor in importance.

Consumers' age affected food preferences. Aged consumers (here defined as the oldest consumer age groups used in the studies) were very specific in their textural requirements. Achieving an easy eating experience was critical for them. In the case of high viscosity gel samples the aged preferred fracturing texture which was not adhesive, nor elastic. In muesli oat flakes, the preferred texture absorbed plenty of milk and was neither adhesive nor needed much mastication. The aged consumers, however, found both fermented oat bran product textures (smooth and lumpy) almost equally acceptable, while the young preferred smooth texture to lumpy one. Thus, as long as the ease of eating was guaranteed, elderly seemed to be willing to accept textural variety in foods. With regard to flavor preferences, the aged tended to prefer more intense flavors. For example, in high viscosity gel samples the elderly preferred the sample with strongest flavor release properties, and they also had more positive attitudes towards flavor amplified fermented oat bran product samples. However, mild flavors were also acceptable for the aged in some food products, like in muesli oat flakes. When this was the case, increased demands were placed on other food attributes, such as texture.

Previous experience was found to affect consumers' preferences only for high-viscosity gel samples, where a reported preference to commercial candies with texture similar to high viscosity gel samples was found to predict preference of actual samples to some extent. No effect of reported previous use frequency of congruent products as the samples was observed in the studies.

In conclusion, food ingredients and processing conditions were found to be efficient ways for modifying sample texture and flavor. The studies indicated that these kinds of modifications are needed to produce foods with adequate textures and flavors for the aged consumers.

PREFACE

Sensory evaluation laboratory was introduced to me during the first week of my undergraduate studies at the University of Helsinki. I knew immediately that this is the place I would like to study and work at. From the present viewpoint, I have been fortunate enough to fulfill this hope.

Many people have helped me during my Ph.D. studies, and the greatest thanks I owe to my supervisor Professor Hely Tuorila who has guided and supported me for many years: from my undergraduate studies to present time. I would like to express my warmest gratitude to her. I would also like to express my gratitude to Professor Lea Hyvönen for providing excellent facilities for me to carry out my research and I also thank her for her support during these years. Furthermore, I sincerely thank Professor Hannu Salovaara for pleasant co-operation.

The reviewers of my thesis Dr. Wender Bredie and Dr. Conor Delahunty I sincerely thank for constructive criticism, comments and suggestions given.

I would also like to express my gratitude to Dr. Katariina Roininen, who first supervised my M.Sc. thesis and later worked as my colleague. She always had time for discussions and time to comment my manuscripts. During these years she has become a dear friend of mine. In addition, I sincerely thank all my colleagues at the University: Sanna-Maija Miettinen, Sari Koskinen, Kaisu Taskila, Anna Bäckström and Suvi Ryynänen. I owe my thanks also to my former workmate Hilkka Holopainen. The stimulating discussions with you and your willingness to help whenever needed have been invaluable.

This study was financially supported by following organizations: the Finnish Graduate School program (Applied Bioscience –Bioengineering, Food & Nutrition, Environment, ABS), the Commission of the European Communities (Agriculture and Fisheries, FAIR, Specific RTD Programme CT95-0574: Understanding and improving the selection and acceptance of foods for health promotion, and the European Commission Quality of Life Fifth Framework Programme QLK1-CT 1999-00010: Healthy Ageing: How Changes in Sensory Physiology and Sensory Psychology Influence Food Preferences), and the Ministry of Agriculture and Forestry, Finland (the National Oats –program). Their support is gratefully acknowledged.

Furthermore, I owe my thanks to my friends, family and relatives, especially to my mother Sinikka and my godmother Aulikki who have encouraged me during these years. To my beloved husband Sami I wish to express dearest thanks.

“The work of researcher is such that you wonder all kinds of things.”
(Pikkukakkonen, a Finnish children’s program)

Helsinki, August 2002

Niina Kälviäinen

LIST OF ORIGINAL PUBLICATIONS

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

I Kälviäinen, N., Roininen, K. and Tuorila, H. 2000. Sensory characterization of texture and flavor of high viscosity gels made with different thickeners. Journal of Texture Studies, 31, 407-420.

II Kälviäinen, N., Schlich, P. and Tuorila, H. 2000. Consumer texture preferences: effect of age, gender and previous experience. Journal of Texture Studies, 31, 593-607.

III Kälviäinen, N., Salovaara, H. and Tuorila H. 2002. Sensory attributes and preference mapping of muesli oat flakes. Journal of Food Science, 67, 455-460.

IV Kälviäinen, N., Roininen, K. and Tuorila, H. 2002. The relative importance of texture, taste and aroma on a yogurt-type snack food preference in the young and in the elderly. Food Quality and Preference. (in press)

RESEARCH INPUT AND AUTHORSHIP OF ARTICLES (I-IV)

Niina Kälviäinen's dissertation is a summary of research reported in four (I-IV) appended articles. The research input and authorship of articles is as follows:

I *Kälviäinen, N., Roininen, K. and Tuorila, H. 2000. Sensory characterization of texture and flavor of high viscosity gels made with different thickeners. Journal of Texture Studies, 31, 407-420.*

The planning of the study as well as the data analysis was carried out by M.Sc. Niina Kälviäinen, Dr. Katariina Roininen and Dr. Hely Tuorila. The experimental study including all empirical work and the preparation of the manuscript were carried out by M.Sc. Niina Kälviäinen. The study was supervised by Dr. Katariina Roininen and Dr. Hely Tuorila and they also participated in writing of the manuscript by giving comments and suggestions.

II *Kälviäinen, N., Schlich, P. and Tuorila, H.2000. Consumer texture preferences: effect of age, gender and previous experience. Journal of Texture Studies, 31, 593-607.*

The planning of the study as well as some of the data analysis was carried out by M.Sc. Niina Kälviäinen and Dr. Hely Tuorila. The experimental study including all empirical work and the preparation of the manuscript were carried out by M.Sc. Niina Kälviäinen. The most of the statistical analyses were conducted by Dr. Pascal Schlich, who also wrote a paragraph into discussion concerning the suitability of statistical method PrefMaX to analyze this kind of data. The study was supervised by Dr. Pascal Schlich and Dr. Hely Tuorila and they also participated in writing of the manuscript by giving comments and suggestions.

III *Kälviäinen, N., Salovaara, H. and Tuorila H. 2002. Sensory attributes and preference mapping of muesli oat flakes. Journal of Food Science, 67, 455-460.*

The planning of the study was carried out by M.Sc. Niina Kälviäinen, Dr. Hannu Salovaara and Dr. Hely Tuorila. The data analysis was carried out by M.Sc. Niina Kälviäinen and Dr. Hely Tuorila. The experimental study including all empirical work and the preparation of the manuscript were carried out by M.Sc. Niina Kälviäinen. Dr. Hannu Salovaara wrote a paragraph into introduction concerning processing conditions of muesli oat flakes. The study was supervised by Dr. Hannu Salovaara and Dr. Hely Tuorila and they also participated in writing of the manuscript by giving comments and suggestions.

IV *Kälviäinen, N., Roininen, K. and Tuorila, H. 2002. The relative importance of texture, taste and aroma on a yogurt-type snack food preference in the young and in the elderly. Food Quality and Preference. (in press)*

The planning of the study was carried out by M.Sc. Niina Kälviäinen, Dr. Katariina Roininen and Dr. Hely Tuorila. The data analysis was carried out by M.Sc. Niina Kälviäinen and Dr. Hely Tuorila. The experimental study including all empirical work and the preparation of the manuscript were carried out by M.Sc. Niina Kälviäinen. The study was supervised by Dr. Katariina Roininen and Dr. Hely Tuorila and they also participated in writing of the manuscript by giving comments and suggestions.

1 INTRODUCTION

Texture is essentially a human experience arising from our interaction with food – its structure and behavior when it is handled (Rosenthal, 1999). Texture perception is a dynamic process that usually takes place in the mouth, where the food is masticated. Despite the majority of textural responses occurring in mouth, humans use several senses to perceive texture, such as vision, touch, and hearing (Wilkins et al., 2000).

According to Lund (1982), consumers are readily able to assess three major food attributes, namely texture, flavor, and appearance. Even though flavor is frequently judged as the most important food characteristic (Schutz and Wahl, 1981; Moskowiz and Krieger, 1995), texture plays a very important role in food identification. According to Murphy (1985), the identification of pureed foods using only taste and odor cues does not always produce the correct answer. When the possibility to use odor cues is also removed, the task becomes even more difficult. In some foods, texture may be the most important food attribute. This is likely to happen if the food has a bland flavor or has crisp characteristics (Szczesniak, 1971).

Texture attributes have strong effects on food perception and liking (e.g. Murphy, 1985; Moskowitz and Krieger, 1995; Daillant-Spinnler et al., 1996; Jaeger et al., 1998). Special requirements for food texture may arise along aging, when many physiological changes are likely to occur. Flavor and texture perceptions change during aging. Taste and olfactory functions are shown to decrease along aging and difficulties in texture perception, like chewing difficulties, may also appear (Chauhan et al., 1987; Fillion and Kilcast, 2001). The percentage of the elderly is growing in most countries (Dichter, 1992). Since the elderly are increasingly important and influential consumer segment nowadays and in future, their needs and desires should be taken in to account when developing new foods (Jellinek, 1989).

This thesis deals with the texture and flavor properties of semisolid and solid foods, and their impact on consumer responses in different age groups. The texture and flavor properties of foods were modified by chancing food ingredients (e.g. thickeners, aromas) or processing conditions (e.g. heat treatment). The consumers' age range varied from teen-agers to elderly. The studies presented in this thesis are divided over three interfaces namely that of relationships between sensory and product properties, the relationships between product properties and consumer preference, and the relationships between sensory properties and consumer preference. Emphasis was placed on finding differences in consumer preferences in different age groups. A wide range of food products was used in order to cover a wide range of hedonic and sensory texture and flavor variations. The objectives of the work were to investigate:

- The effects of food components and processing conditions on food texture, taste and, aroma (Studies I, III, and IV).
- The consequences of such food texture, and flavor modifications on consumer preference evaluations with emphasis on different age groups (Studies II, III, and IV).
- The relative importance of texture, taste, and aroma on consumer preference with emphasis on different age groups (mainly Study IV, but also Studies II, and III).

2 LITERATURE REVIEW

The literature review inspects the textural aspect of semisolid and solid foods, and examines them from different viewpoints. The literature review concerns flavor and texture perception and how these perceptions may change along aging. It introduces texture classification methods and texture-flavor interactions. The literature review also takes a look at factors affecting texture preferences and how food texture can be measured.

2.1 Flavor and texture perception

2.1.1. Flavor perception

In general, flavor is considered as a combination of aroma, taste and trigeminal perceptions from stimulation of the mouth and nasal area. Food texture, 'mouthfeel' properties, salivation and oral manipulation affect flavor release together with temperature, surface area and enzymes present (Laing and Jinks, 1996; Taylor, 1996; Taylor and Linforth, 1996).

Volatile molecules of foods lead to aroma perception. These components are sensed in the roof of the nose, at the nasal cavity. The volatile components are carried to the nasal cavity with air through the retro-nasal pathway during eating. In the nasal cavity there are circa 1000 types of odor receptor proteins to which the odorants may bind (Laing and Jinks, 1996; Taylor, 1996). When an odorant binds to a receptor protein, its chemical energy is transformed into electrical energy, which is then transmitted to olfactory structures in brain. Each odorant produces its own characteristic spatial map in the olfactory bulb and other brain structures. The number of receptor cells involved is odorant and concentration dependent (Laing and Jinks, 1996).

It is common view that only five types of taste qualities exist, namely sweet, salty, sour, bitter and umami. Non-volatile molecules of foods may produce taste perceptions. These non-volatile compounds interact with taste-sensitive regions of the oral cavity, i.e. with taste receptor cells. According to literature, at least five pathways are involved in the reception and transduction of tastants. For example, sugars bind to receptor proteins and activate two pathways. Salty compounds again alter the electrical status of receptor cells either by permeating through ion channels in the membrane to the interior of the receptor cell, like NaCl, or by diffusing between taste receptor cells, like KCl. There are two major theories how taste information is coded into the brain. According the “pattern” concept, taste receptor cells respond with different sensitivities and firing rates to the tastants producing a unique pattern of responses across cells that is characteristic to each tastant. The “labelled line” theory suggests that each tastant is sensed in its own separate types of receptor cells and the information is then passed to gustatory centers in the brain trough independent channels (Laing and Jinks, 1996).

The third component in flavor forms the activation of trigeminal nerve endings in the oral and nasal areas by volatile and non-volatile substances. Activation of the trigeminal nerve gives sensations of chemical burn (e.g. hot chili pepper) and irritation (e.g. carbondioxyde).

Since the sensations of odor, taste and the trigeminal sense are difficult to locate and separate analytically when eating, the term flavor is used to accommodate these perceptions. Flavor perception is time dependent, as food changes during eating because of many different factors, like salivation and mastication (Taylor and Linforth, 1996). In general, flavor is often judged as the most important food characteristic and thus, has very strong impact on food preferences and palatability (Schutz and Wahl, 1981; Moskowiz and Krieger, 1995).

2.1.2 Texture perception

Texture perception begins with the structure of a food material (i.e. how the molecules or microstructures are arranged geometrically). When this structure is put in to the mouth or manipulated with our hands, it undergoes changes such as size reduction and moistening caused by salivation. The food structure, together with masticatory action, produces stimuli, which are converted by neural factors into a texture response from the brain. These responses can be converted into intensity ratings of certain textural attributes, which are usually rated by trained sensory panels. Furthermore, texture responses can be converted into preference evaluations, typically rated by consumers (Hutchings and Lillford, 1988). In addition to texture perceptions that occur in the mouth, vision, touch, and audition also play important roles in texture perceptions (Heath and Prinz, 1999; Kilcast, 1999).

Visual texture is the first textural attribute that is noticed when evaluating textural properties of foods. Visual texture judgements are largely dependent on prior eating experiences. Vision creates expectations of the texture in the mouth or in the hands. If these expectations are violated, the food may be rejected (Szczesniak and Kahn, 1971). Textural properties that can be evaluated visually include shine, and surface roughness and reflection, to mention but a few (Lawless and Heymann, 1998).

Tactile sense, i.e. *the sense of touch,* is also used for texture evaluations. Texture evaluations can be made either directly, mainly by touching or manipulating the food material with the fingers, or indirectly by touching the food with a knife, fork, etc. (Brennan, 1984; Kilcast, 1999). Civille and Dus (1990) introduced a list of texture attributes that can be used for describing the 'handfeel' properties of paper and fabric. These attributes can be adapted to food product evaluations. Texture attributes that can be evaluated manually include mechanical (such as force to compress), geometrical (gritty, fuzzy), and moisture (oily, wet) attributes. Most of these texture properties are perceived by contact between skin and material surfaces. Moving skin (e.g. finger) across the surface (e.g. skin of an orange) sets up vibrations in the skin which are thought to be a critical sensation in tactile texture perceptions (Christensen, 1984). It has been demonstrated that it is possible to differentiate textural properties of food samples, such as cheeses, using either hand or mouth evaluations (Drake et al., 1999). Lips are also important for tactile texture perception. They are especially sensitive to assessing surface roughness and other related food attributes (Heath and Prinz, 1999). However, when it comes to evaluating the degree of certain textural attributes (e.g. crispness), evaluations done in the mouth are found to be more exact than those done with the hands (Roos et al., 1998).

The oral cavity is very important for food texture perception. There is a dense innervation of nerve fibers and receptors located in different regions of the oral cavity, such as the lips, palate, and tongue. Together these sensory systems are responsible for detecting sensations of touch-pressure, pain, warmth, cold, and joint position. Most of the texture sensations are perceived when the food is manipulated, e.g. deformed or moved. The touch-pressure sensory qualities (somaesthetic) are detected by several classes of rapidly and slowly adapting neural elements that respond to small deformations of the skin. In addition, *kinaesthetic sensations* provide information on movement and position of the mandible, which is important when particle size, i.e. the shape of food before and during mastication, is determined. Joint receptors contribute to the estimation of such food texture attributes as hardness (Christensen, 1984).

In addition to vision and touch, *hearing (audition)* is an important sense for texture evaluation. Drake (1963) observed differences between chewing sounds produced when biting different foodstuffs. According to Vickers and Wasserman (1979), two basic sensory criteria that distinguish food sounds are loudness and unevenness or discontinuity. Hearing is especially important when the crispness or crunchiness of food is considered. Drake and Halldin (1974) observed that various crispy foods differed according to their crushing sounds. Thus, it is possible to differentiate crisp and crunchy foods based on eating sounds. Crisp foods tend to have a higher-pitched biting sound than their crunchy counterparts (Vickers, 1984). Similarly, it is possible to differentiate between fresh and stale potato or tortilla chips by listening to the biting sounds. Fresh chips or tortillas generate louder sounds with greater numbers of higher frequency components than stale ones (Lee III et al., 1988). Sensory evaluations of crispness and the sounds recorded when crushing food samples (e.g. biscuits, wafers, and potato chips manipulated by humidity) are found to correlate significantly with each other (Mohamed et al., 1982; Seymour and Hamann, 1988). Mohamed et al. (1982), in studying the correlation of instrumental and sensory properties of fried foods, stated that the sounds produced while eating are important for both evaluation and enjoyment of crisp foods. Factors affecting texture perception according to the literature discussed in this section are presented in Figure 1.

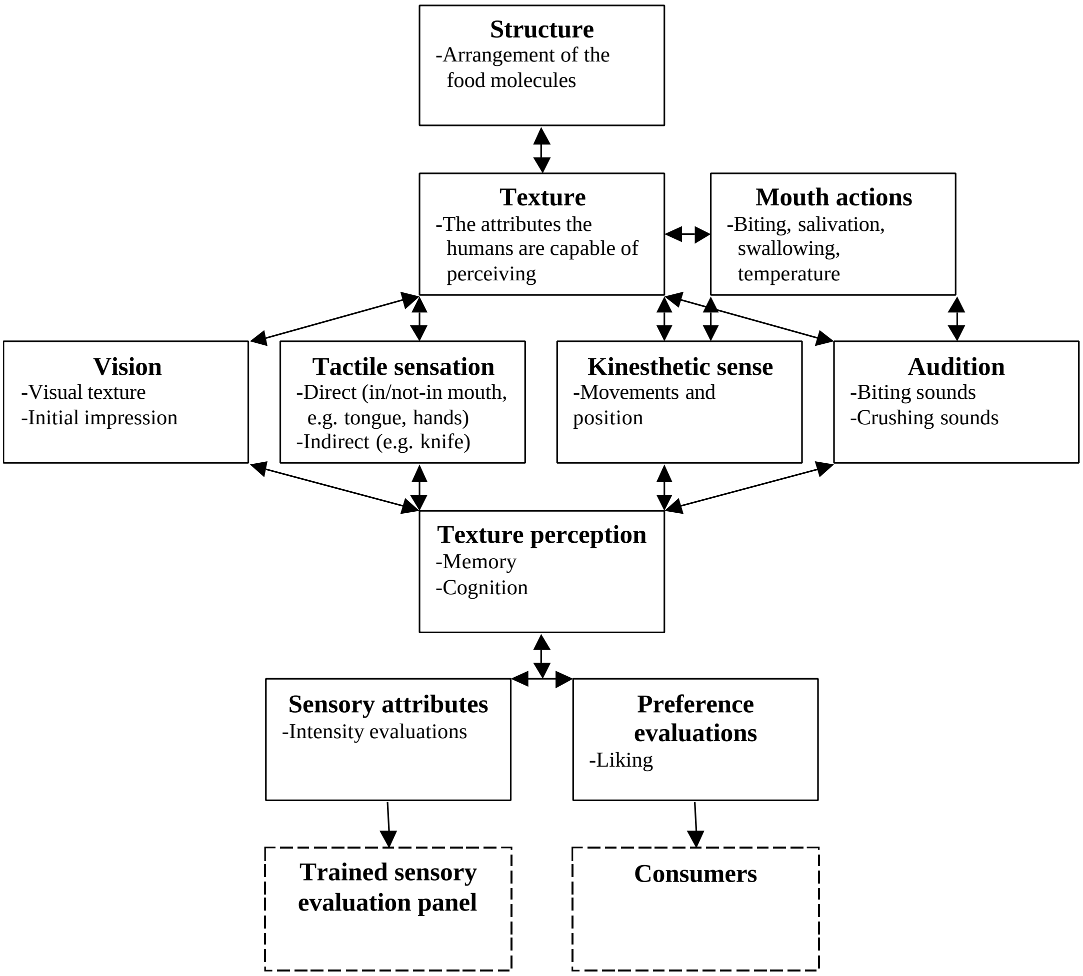

Figure 1. The outline of factors affecting texture perception.

2.1.3 Flavor and texture functions from the young to the elderly age

Many physiological changes occur during aging and many of these changes affect food perception. The most remarkable changes related to food perception are diminished olfactory and taste function. Even though, declines in olfactory and taste functions occur along aging, these changes are not identical in each case. In fact, the sensory functions of the elderly indicate larger individual variability in comparison with the young. The olfactory and taste functions of some elderly are somewhat intact, while the others may suffer from remarkable declines (Cowart, 1989; Weiffenbach, 1991). The changes in texture perception are also likely to occur and these changes are likely to affect food perception too.

Olfactory function diminishes during aging (Cauhan et al., 1987; Schiffman, 1994), and this decline is even more predominant than that of taste function (Stevens et al., 1984). Aging affects both, olfactory thresholds and odor identification ability (Covart, 1989). The ability to identify food flavors may diminish and flavor intensity evaluations may decrease (Murphy, 1985; Stevens and Cain, 1986; Brand and Bryant, 1994). Because flavor perception is strongly dependent on the volatile components of the foods, diminished olfactory function decreases flavor perception of the elderly (Brand and Bryant, 1994). Some studies indicate that elderly have higher optimal preferred flavor concentrations than young (de Graaf et al., 1996; de Jong et al., 1996).

Taste function of the elderly has been studied with basic tastants. The studies have shown that the elderly tend to have higher taste thresholds than the young (e.g. Bartoshuk et al., 1988; Chauhan et al., 1987). Some studies indicate that diminished taste function is tastant dependent (Weiffenbach, 1991). For example, according to Kaneda et al., (2000), sweetness perception diminish less than sourness perception along aging. Coward (1989) found no effects of aging on sweetness, whereas in the cases of salty, sour and bitter tastants the effect of aging was observed. Elderly are also less sensitive to increases in taste concentrations in comparison with young (Cauhan and Hawrysh, 1988; Stevens at al., 1995; Zandstra and de Graaf, 1998). Because of these declines in taste function, elderly may prefer higher taste concentrations than young. This was the case in the studies of de Jong et al. (1996) and Zandstra and de Graaf, (1998), who observed that elderly preferred higher sucrose concentrations in breakfast items and in orange beverages than young.

Aging affects texture perception. In brief, lacking of natural teeth and denture wearing, which are likely to occur along aging (e.g. Wynne, 1999), are found to interfere texture perception. Denture wearing may make it difficult to eat certain hard foods, like nuts and raw carrots (Horton, 1987). In addition, muscles may fatigue easily when eating tough food that need plenty of mastication (Peleg, 1993). The effects of aging on texture perception and its relation food preferences are discussed in more details in section 2.4.1.

2.2 Classification of sensory food texture attributes

The terms ‘structure’ and ‘texture’ commonly appear when considering food texture, and they are sometimes confused with each other. Both have specific meanings. The *structure* of the food can be defined as “the nature of and relationship between component parts of a body or material”. The word *texture* again is defined as “the attribute of a substance resulting from a combination of physical properties, which are perceived by the senses of touch (including kinaesthetic and ‘mouthfeel’), sight, and hearing. Physical properties may include size, shape, number, nature, and confirmation of constituent structural elements” (Jowitt, 1974).

Texture perceptions are caused by food structure (Hutchings and Lillford, 1988), and structure can be classified into four levels based on how it is observed. These classes are chemical, electron microscopic, light microscopic, and gross observation. The *chemical structure* deals with the molecules that make up the food and how these molecules interact with each other. The *electron microscopic level* has to do with the aggregation of molecules and their assembly into components, and the *light microscopic level* deals with the same items on a larger size scale. The *gross level* considers structural features that can be perceived by the human senses, such as texture attributes (Kilcast and Lewis, 1990).

Texture attributes can be further divided into different categories. The most common classifications are presented in Table 1. These classifications are still used today, even though they were developed decades ago. No new and universally accepted categorizations have appeared in recent years.

Table 1. Common classifications of food texture attributes

Texture classes	Definition of the class and possible sub-classes	Examples of the attributes		Reference
I Mechanical	Behavior of the material under stress or strain	*Primary attributes:* Hard, cohesive	*Secondary attributes:* Brittle, chewy	Szczesniak, 1963
II Geometrical	1) Size- and shape-related attributes	Smooth, gritty		
	2) Shape- and orientation-related attributes	Pulpy, flaky, crystal		
III Other attributes	Mouthfeel qualities related to perception of moisture and fat content	Oily, greasy		
I Primary characteristics	1) Analytical characteristics 2) Particle size and shape, size distribution 3) Air content, air cell site and distribution			Shermann, 1969
II Secondary characteristics	Combinations of two fundamental texture properties	Elasticity, viscosity, adhesion		
III Tertiary characteristics	Combinations of two or more secondary attributes	Hard, brittle, lumpy, creamy, sticky		
I General texture attributes	Structure, texture, and consistency			Jowitt, 1974
II Behavior of the material under stress or strain		Firm, hard, soft		
III Structure of the material	1) Particle size or shape	Juicy, fine		
	2) Shape and arrangement of structural elements	Flaky, fibrous		
IV 'Mouthfeel' characteristics		Juicy, mushy		

2.3 Texture-flavor interactions

2.3.1. Texture effects on basic tastes

Texture sensation does not merely occur as a response to teeth, isolated from other stimuli. In a normal eating situation, interactions between texture, taste, and aroma take place. One of the most well-known texture-taste interactions is that increasing viscosity reduces perceived taste intensity (Pangborn et al., 1978; Christensen, 1980; Calviño et al., 1993). Calviño et al. (1993) studied the effects of carboxymethylcellulose and gelatin solutions on perceived sweetness and bitterness. The study demonstrated that increasing consistency of the samples reduced the perceived intensity of these two tastes. A similar effect was found when thickness of tomato juice, orange drink, and coffee was increased with hydrocolloids, reducing perceived tastes of sourness and bitterness. This reduction effect is hydrocolloid-, drink- and taste-specific (Pangborn et al., 1978). For example in case of sweetness, produced by sucrose and fructose, taste reduction caused by increasing viscosity is based on the physiologic fact that to be tasted the sugar compound must diffuse to the surface of the taste buds on the tongue. The diffusion rate is dependent on the mobility of the tastant in the matrix and thus depends on the concentration of the tastant and the rheological properties of the thickener used (Kokini et al., 1982; Kokini, 1985).

3.2.2. Texture effects on odor

In addition to texture-taste interactions, texture affects odor perceptions obtained by sniffing ortho-nasally. According to Pangborn and Szczesniak (1974), the addition of hydrocolloids in water solutions generally reduces odor intensity. A similar finding was made with beverages: an increase in hydrocolloid concentration reduced aroma intensity remarkably (Pangborn et al., 1978). The reason suggested for odor reduction was that the large hydrocolloid molecules entangle and trap to small odor molecules, which results in reduced vapor pressure of the solutions. It was supposed that the texture-odor interactions are linked to molecule size and to polarity and volatility of the odor and flavor molecules (Pangborn and Szczesniak, 1974). More recent literature has shown that increasing hydrocolloid concentration reduces the partition coefficients of volatile compounds. The reduction is caused by interactions between particular volatile molecule and particular hydrocolloid (Godshall, 1997).

3.2.3 Texture effects on flavor

Besides texture interactions with basic taste and odor, texture-flavor interaction has been reported. In the case of normal eating and sensory evaluation, flavor is usually defined as perception of taste and aroma together, obtained retro-nasally in the mouth during eating. Taste and odor interactions occur when evaluating flavor. Cliff and Noble (1990) noticed that increasing glucose (tastant) level raised the fruitiness (flavor) evaluations of glucose-aroma-water solutions, even though the aroma (peach) level maintained stabile. Vice versa, when aroma level was raised, the sweetness evaluations increased regardless of constant glucose level. Similar results have been obtained with different aromas and tastants (Frank and Byram, 1988; Frank et al., 1989; Stevenson et al., 1999). Thus, tastes are capable to increase aroma intensities and conversely, aromas may increase taste sensations (Noble, 1996). Tactile sensations play also significant role in flavor perception (Noble, 1996). In general, an increase in food viscosity reduces perceived flavor intensity (Pangborn and Szczesniak, 1974; Pangborn et al., 1978). Baek et al. (1999) indicated that increasing gelatin concentration of gel-type samples resulted in decreased perceived sensory flavor intensity. Similar results were obtained by Guinard and Marty (1995), who demonstrated that firm gels released flavor of lower intensity than soft gels. In addition to diminished flavor intensity, increasing mechanical strength of the gel-type samples results in prolonged flavor perception (Wilson and Brown, 1997). This may partly be due to the total surface area of a firm sample available for flavor release increasing at a slower rate during mastication than that of a fragile sample. Thus, the total chewing time needed to masticate firm samples is also longer than that needed for fragile samples (Wilson and Brown, 1997).

As described above, texture affects taste, odor and flavor perceptions of foods. Furthermore, different tastants have been reported to have effects on perceived textures. Sucrose has been demonstrated to increase physically measured viscosity of hydrocolloid solutions, whereas sodium chloride and caffeine decrease apparent viscosity. Citric acid, in turn, decreases both apparent and physically measured viscosity of similar hydrocolloid solutions (Pangborn et al., 1973). The addition of a specific flavorant (butyric acid) has also been shown to reduce the sensory and physically measured viscosity of hydrocolloid samples (Pangborn and Szczesniak, 1974). Thus, all interactions discussed above are tastant, aroma and texture specific, and all food components together determine the how taste, odor, flavor and texture of foods are perceived (Pangborn and Szczesniak, 1974; Godshall, 1997).

2.4 Factors affecting texture preferences

Texture perception is a versatile matter. However, when consumers consider texture, they most likely think it in the context of texture preferences. Many factors affect texture preferences, a few of which are discussed in this section.

2.4.1 Age

The first food given to infants has a high liquid content. As the infant grows, behavioral signals, such as frequent need for feeding or return to night waking, indicate that it is time to introduce solid foods (Harris, 1988). According to in-depth interviews of mothers with four or more children by Szczesniak (1972), and another set of interviews of female homemakers (Sczcesniak and Kahn, 1984), textures eaten by infants are mostly soft, smooth, mushy, and creamy as their ability to eat other food types is limited. When children get teeth, the ability to chew develops and the possibility to experience new texture sensations appears. These interviews showed that young children prefer relatively chewy and rough foods that are easy to manipulate in the mouth over lumpy, greasy, or stringy foods. Crisp and crunchy textures are also favored. Young children have been reported to prefer simple textures and raw vegetables over cooked ones. When children become teenagers, their knowledge of texture increases and they become very texture-conscious. This was found to be true in the study of Szczesniak (1972), who interviewed 20 teenagers in depth and had 198 teenagers to fill out a questionnaire on foods and food texture. She concluded that at this age textural preferences move towards aggressive and firm textures like crunchiness. Texture also becomes one of the main reasons for disliking certain foods: mushiness, softness, stringiness, and toughness are commonly reported as reasons for dislike. Thus, texture assumes a greater importance for teenagers when it has a negative connotation. When Kühn and Thybo (2001) studied young children's (9 to 13 years) apple preferences, they observed that special texture attributes (e.g. skin toughness) were critical to dislike, while for liking an apple texture failed to receive much attention.

As an adult, liking of texture contrasts increases, which means that two different textures (such as crisp and creamy) combined in the same food or dish are favored. This was observed when studying the results of interviews of female housekeepers (Szczesniak and Khan, 1984). The vocabulary to describe texture attributes of food also develops (Oram, 1998). Based on several series of in-depth interviews of adult subjects, certain texture attributes tend to be associated with food quality. For example, "good" meat is expected to be tender and poor meat tough, and a properly prepared cake should be light and airy, while cake of poor quality is expected to be soggy or rubbery (Szczesniak and Kahn, 1971).

Further aging causes many physiological changes affecting texture perception, and some food textures may become problematic. Difficulties may arise when the food eaten requires a large force to break down (e.g. nuts, hard candies, raw carrots). Foods that need extensive mastication before swallowing may also be problematic as prolonged mastication may cause muscles to fatigue (tough meat or dry fruits). Moreover, dry food materials (biscuits) may be hard to swallow because salivation is often reduced in old age. Foods that adhere to teeth and dentures (candies, dry fruits) and foods with sharp broken pieces can also be troublesome (Peleg, 1993).

According to the National Diet and Nutrition Survey (n = 1275) 50% of the elderly (age 65 or over) living on their own in the United Kingdom wear dentures (Wynne, 1999). Those with dentures are less likely to consume foods that need much chewing, like apples, oranges, raw carrots, nuts, and bread. The number and distribution of natural teeth thus appears to be related to the ability to eat a variable diet (Smithers et al., 1998; Wynne, 1999). Dentures may cause difficulties in texture perception. Strong forces required for biting hard foods may cause pain in mouth tissues beneath dentures. Removable dentures are also known to reduce mastication efficiency (Nagao, 1992). In addition, salivation has essential role in masticatory function as it lubricates the food during chewing (Fillion and Kilcast, 2001). Studies indicate that many elderly have decreased salivary output. This is most likely caused by certain treatments, like drugs or chemotherapy, rather than by normal aging (Ship, 1999). Brown and Braxton (2000) suggested that, at least in the case of biscuits, ease in eating might be a reason for preferring particular foods. Despite their age, the number of natural teeth, or denture wearing, the elderly want to experience textural variety, which is an important element of food perception (Horton, 1987). Jellinek (1989) recommended that food manufacturers produce foods designed especially for the elderly that have lively texture and taste.

Some points should be considered when studying literature discussed above. Firstly, all of these studies were conducted in western countries. Whether these texture-related matters are also true in nonwestern countries is not known. Secondly, many of these studies are relatively old. Children, teenagers, and adults of today are likely somewhat different than they were about in the 1970s and 1980s. Thirdly, especially in the case of young children, information about texture preferences was mostly gained by interviewing their mothers and not directly from them. Characteristic features of texture perceptions during different life periods are presented in Table 4. The information has been combined from the literature discussed above.

Table 2. Texture perceptions during different periods of life based on the literature[(1].

Period of life	Age range	Textures preferred	Characteristic features of texture perception
Infant	< 10 months	Smooth, mushy, creamy	Chewing capability limited
Young children	1 – 10 years	Chewy, rough, crisp, crunchy	Simple textures preferred
Teenager	13-19 years	Firm, crunchy, aggressive	Texture of great importance when it has negative connotation
Adult	19-65 years	Contrasting textures	Texture associated with food quality
Elderly	> 60 years	Easy-to-eat	Dentures and lack of natural teeth may cause difficulties with certain foods. Textural variety still important

[(1] Szczesniak and Kahn, 1971; Szczesniak 1972; Sczcesniak and Kahn, 1984; Horton, 1987; Jellinek; 1989; Nagao, 1992; Peleg, 1993; Oram, 1998; Smithers et al., 1998; Wynne, 1999; Brown and Braxton 2000; Kühn and Thybo, 2001.

2.4.2 Gender

Word association studies done in the 1960s and 1970s in the United States strongly illustrated that females were more aware of food texture than males (Szczesniak and Kleyn, 1963; Szczesniak, 1971; Szczesniak and Khan, 1971). The explanation given was that females were more involved with buying, preparing, and serving of food (Szczesniak and Khan, 1971). Another word association study conducted in Europe showed that females tended to give more texture-related responses than males when different types of foods were mentioned (Rohm, 1990). However, males rated texture as more important than the females when asked to evaluate the relative importance of appearance, flavor, and texture to acceptance of 94 food products listed in the questionnaire (Schutz and Wahl, 1981). When females were asked to list texture attributes that would be appropriate and desirable for males they named juicy, heavy, thick, crumbly, flaky, soft, and chewy (Szczesniak and Khan, 1984). While texture preferences may be gender specific, these differences may simply reflect differences in general food preferences between genders.

Why females and males differ in texture preferences is not clear. Differences in texture preferences may, for example, be related to the means of data generation. The genders may be differently forthcoming with information in interview situation and when completing questionnaires. Differences may occur because of gender roles. Culture may also play a significant role together with food availability. In any case, differences between genders do exist. Chocolate is reported to have unique texture properties and ‘mouthfeel’ (Hoskin, 1994). Hetherington and Macdiarmid (1993) found some gender-related differences in consumers’ attitudes towards chocolate when studying consumers who reported having strong cravings for chocolate and identified themselves as “chocholics”. They observed that 92% of these “chocholics” were female. However, the question whether the unique texture properties and ‘mouthfeel’ of chocolate have to do with females’ higher percentage in “chocholics” remains unanswered.

2.4.3 Socioeconomic class

Szczesniak and Kleyn (1963) studied the effect of education on texture awareness by using word association tests. They divided the subjects into three groups according to type of their education: nontechnical, technical work in a nonfood area, and technical work in a food area. Apparently, technical personnel, both food and nonfood, was more texture-conscious than nontechnical personnel. Another word association test conducted in Austria demonstrated that subjects who had an education in food technology gave more texture-related responses than those outside the field of food technology (Rohm, 1990). Schutz and Wahl (1981) obtained a positive correlation between education level and perceived relative importance of texture. In addition to education, socioeconomic class affects texture awareness. Consumers belonging to higher socioeconomic classes gave more texture-related responses in word association tests than those belonging to lower socioeconomic classes (Szczesniak, 1971, Szczesniak and Khan, 1971). In-depth interviews revealed that consumers belonging to higher socioeconomic classes seem to understand the idea of texture better than those of lower socioeconomic status. The explanation suggested was that increased education provides experience in dealing with generalized concepts and applying abstractions to concrete cases (Szczesniak and Khan, 1971). Szczesniak (1990) further suggested that high socioeconomic class is usually related to a greater degree of schooling, which again may be related to the level of exposure to different experiences and different foods. These factors together may lead to greater awareness and appreciation of texture.

2.4.4 Other factors affecting texture preferences

The *type of food* affects how texture is noticed. For crisp or crunchy foods, texture is typically noted and appreciated. Similarly, if the food has a bland flavor, the importance of texture increases (Szczesniak, 1971). *Expectations* are also important to textural perceptions and preferences. The role of consumer expectations on the acceptance of novel foods was studied by Cardello et al. (1985). They concluded that hedonic response to food is a function of the degree to which expectations about particular foods are matched to actual experience. However, no texture-related expectations were examined in this study. According to Szczesniak and Khan (1971) texture awareness increases substantially if the texture does not meet expectations. When expectations are not filled, it may easily lead to rejection of a particular food. People tend also to like *texture contrasts* in foods. According to Szczesniak and Khan (1984), pleasant texture combinations involved either two very different texture types (crisp and creamy) or two highly similar texture types (soft and creamy). Desirable texture combinations are present in several food types: in candies, for instance, a brittle candy shell may surround a chocolate layer with a peanut center (Lawless, 2000). Besides texture contrasts, high levels of *dynamic contrast* evoke positive reactions. Food texture may change markedly during mastication. These dynamic contrasts may be phase transitions, such as melting of chocolate or icecream, or other extensive texture changes, as in crisp and crunchy foods (Hyde and Witherly, 1993; Lawless, 2000).

Also *eating situation* and *the time of the day* affect texture preferences. According to Szczesniak and Khan (1984), crisp, soft, creamy, and smooth textures are preferred during breakfast, whereas tender, crisp, firm, and chewy textures combined with creamy soft, flaky, and fibrous choices are desirable at dinner. When snacking and eating for amusement, crisp and crunchy textures are desired. The range of acceptable textures seems to be most limited at breakfast, and the broadest at dinner (Szczesniak, 1990). *Previous texture preferences* are also known to affect hedonic ratings. Baron and Penfield (1993) divided consumers into two groups according to their reported texture preferences. The group preferring a soft bean texture to a crisp one gave higher hedonic ratings to boiled, i.e. soft, beans as compared with steamed, i.e. crisp, beans in sensory evaluation.

Finally, *culture* affects food preferences (Rozin and Vollmecke, 1986) through availability, food traditions, and exposure to specific food products. One example of culture-related food preferences is the abundant use of chili pepper in some cultures (Rozin, 1990).

2.5 Measurement of food texture

2.5.1 Trained sensory panels

Sensory evaluations of texture produce information on how people perceive and react to texture when using products (Lawless and Heymann, 1998). To obtain reliable and objective sensory measurements, trained sensory panels are needed for texture evaluations. Without appropriate training, subjects use their own frames of references in the evaluation. These subjective references differ because of different sensory experiences, cultural background, environment factors, and general personal history. Through training, it is possible to develop a common frame of reference to be used during evaluations. Such a panel would be able to provide similar qualitative and quantitative responses (Munõz and Civille, 1998).

A further basic demand for successful sensory texture evaluations is that texture attributes be defined in a way that each panelist understands them similarly. For this purpose, textural terminology, which gives detailed definitions of food attributes, is a useful tool. For example, the article of Jowitt (1974) includes an excellent list of several texture attributes and their definitions. To obtain accurate and reliable sensory measurements of texture attributes, and to develop common frames of reference, standard rating scales have been developed. Szczesniak (1963) introduced standard rating scales for hardness, brittleness, chewiness, gumminess, viscosity, and adhesiveness. Each scale has several reference materials, which cover the range of intensity sensations found in foods. For example, the hardness scale has nine references ranging from cream cheese (point 1) to peanuts (6) to rock candy (9). Serving temperature, size, and manufacturer are also defined. Munõz (1986) introduced additional standard rating scales for wetness, adhesiveness to lips, roughness, self-adhesiveness, springiness, cohesiveness of mass, moisture absorption, adhesiveness to teeth, and manual adhesiveness. The problem with these standard rating scales is that reference materials may be hard to obtain worldwide. The availability may also fail if the manufacturing of the reference materials ends or the recipe changes. Therefore, reference standards especially selected for particular tests are often used. Reference standards help panelists to develop accurate terminology, determine anchors, and identify most important product characteristics. The reference standards are also useful for demonstrating the effects of ingredients on actual sample materials, and they shorten training time, enable documentation of terminology, and provide productive tools for discussion (Rainey, 1986).

Discrimination tests are practical when the aim is to establish whether differences exist between samples. These tests enable detection of small overall differences in sensory characteristics. Again, attribute intensity ratings are useful when information considering the amount of perceived difference is needed. The use of a trained sensory panel is essential when conducting these tests (Kilcast, 1999). If the aim is to study both qualitative and quantitative product differences, i.e. attributes differentiating products and degrees of these differences, descriptive analyses are needed. Perhaps one of the most common ways to study qualitative and quantitative texture differences is to use texture profile analysis (Lawless and Heymann, 1998). The method takes into account the dynamic nature of texture perception. Thus, it measures the texture attributes in the order of appearance: from prior mastication phase to first bite, masticatory phase, residual phase, and finally swallowing. The method requires extensive training of the panelists, but offers the advantage of standard rating scales and reference materials. The aim is to achieve complete agreement and similar evaluation behavior and use of the scale (Anon., 1994; Lawless and Heymann, 1998).

2.5.2 Consumers

The consumer texture profile method is recommended by Szczesniak et al. (1975) when consumers' texture perceptions, other than liking, are of interest. The method uses a list of descriptive texture terms developed by a trained texture profile panel. The terms 'good' and 'bad' are added to the list to obtain an overall measure of texture quality. The subjects are asked to evaluate given attributes on a 6-point scale anchored 'not at all' – 'very much so'. The problem is that consumers may not understand all the texture attributes as similarly as the trained panelists do (Munõz and Civille, 1998). A common opinion is that consumers can evaluate a few "simple" texture attributes (like hardness), but more technical attributes (like fracturability) are not suited for consumer testing. To evaluate these "simple" attributes, the relative-to-ideal scale is recommended. The scale is anchored from, for example, 'not nearly too hard' to 'much too hard', with 'just right' being in the middle. The scale measures the desirability and optimum levels of attributes from a consumer point of view (Lawless and Heymann, 1998).

2.5.3 Combining the data of trained sensory panel and consumers

Because consumers are generally not familiar with texture or other food attribute intensity ratings, it is problematic to know which food attributes predict consumer preferences. One of the predominant ways to achieve this information is to combine descriptive sensory data of trained sensory panel and consumers' preference data with a statistical method called external preference mapping. When this method is used, consumers need only express their relative like or dislike, and no intensity ratings are required from them. This method enables study of the sensory properties that direct consumer preference and which product differences are important when determining consumers' acceptance (Greenhoff and MacFie, 1994). A review of relatively recent preference mapping studies is presented in Table 3. This consists of studies in which the preference mapping method has been used to study texture and flavor attributes and their effects on consumer preference evaluations. It also provides examples of preferred attributes, factors affecting consumer segmentation (if specified in the study), and the most important attributes predicting consumer preferences (if specified). The most important attributes are selected on the basis of authors' opinions and figures printed in the articles.

The preference mapping method is practical, for example, when targeting foods for special consumer groups. It is possible to identify which consumers prefer which types of food products. The studies presented in Table 3 indicate that for example age, income level, marital status, gender, and family can alter consumers' food preferences (Murray and Delahunty, 2000; Richardson-Harman et al., 2000). The food-related factors affecting consumers' preferences can also be studied. The review of the recent preference mapping literature indicates that flavor of the food is often most important factor affecting consumers' preferences (Shepherd et al., 1987; Helgesen et al., 1997; Pagliarini et al., 1997). However, the texture and appearance may also play significant roles (Daillant-Spinnler et al., 1996; Meullenet et al., 2001). Thus, the effect of these factors on preference is food dependent.

Table 3. A review of preference mapping studies.

Sample (No. of samples)	Attributes varying in the samples	Attribute categories evaluated[1]	Examples of preferred attributes	Factors affecting consumer segmentation	The most important attribute category predicting preference	Reference
Commercial Spanish cheese (11)	Origin, type of milk, ripening time, smoking	O, F, T	Smoky (O), nutty, buttery (F), firm, granular (T)	-	-	Bárcenas et al., 2001
Commercial cheddar cheese (8)	Not specified	A, O, F, T	Shiny (A), salty, acid (F), moist, smooth (T)[2]	Age, income, marital status	-	Murray and Delahunty, 2000
Commercial mozzarella cheese (9)	Milk (cow vs. buffalo), fat (low vs. full fat)	A, O, F, T	Yogurt odor (O), sweet, milky (F), elastic, juicy (T)	-	Flavor	Pagliarini et al., 1997
Commercial strawberry yogurt (23)	Country of manufacture, fruit concentration etc.	A, F, T	Pink (A),creamy, vanilla, sweet (F), homogenous (T)	-	-	Ward et al., 1999
Commercial liquid dairy products (10)	Thickening (yes/no), dried or fresh product, fat content	A, F, T	Creamy, buttery (A), creamy, buttery, sweet, vanilla (F), viscose slippery (T)[2]	Age, gender, income, country of origin, family (children)	-	Richardson-Harman et al., 2000
Powdered chocolate milk (9)	Cocoa and thickener concentration	A, O, F, T	Dark color (A), chocolate (F), viscosity (T)	Age	-	Hough and Sánchez, 1998
Commercial dried tomato soup (8)	Not specified	A, O, F, T	Tomato flavor (F)	-	Flavor	Shepherd et al., 1988
Ranch salad dressing (9)	Fat and garlic flavor concentration	F, T	Garlic flavor (F), low fatty/creamy characteristics (T)	-	Garlic flavor	Yackinous et al., 2000
Commercial rice (21)	Origin, variety, cooking time needed	A, O, F, T	Whiteness (A), cooked grain, nutty (F), cohesiveness, visual thickness (T)	-	Appearance	Meullenet et al., 2001
Apples (12)	Variety	A, O, F, T	Shiny (A), sweet, acid (F), juicy, hard (T)	-	Texture	Daillant-Spinnler et al., 1996
Commercial fermented lamb sausages (6)	Not specified	A, O, F, T	Acid (O), lamb, acid (F), juicy (T)[2]	Age, gender	Flavor	Helgesen et al., 1997

[1] A = appearance, O = odor/aroma, F = flavor, T = texture [2] The most preferred attributes depend on the consumer segment

As Table 3 shows, external preference mapping is practical method providing versatile picture of sensory properties of foods as well as their effects on consumer preferences. There are, however, some considerations that must be taken into account when using preference mapping. For example, the minimum number of samples needed to perform a successful test is six, although a larger sample size is strongly recommended, and each subject has to evaluate all the samples (Greenhoff and MacFie, 1994; McEwan, 1996). Evaluating too many samples may be wearing for consumers. Consumers may also be very selective in which product attributes they pay attention to, and not all sensory attributes are equally important for them when evaluating multi-attribute samples (Jaeger et al., 2000). Thus, consumers differ where the focus of their attention is: some may be flavor orientated, and other texture or appearance orientated (Moskowitz and Krieger, 1995). The way the trained panelists perceive products differs from that of consumers. The trained panelists are expected to quantify the intensity of all attributes that can be perceived. They evaluate ‘all’ attributes, but focus on one attribute at the time. In spite of these facts, preference mapping offers a practical way to study preference structures underlying consumer preferences, and the method is widely used in product development and optimization (McEwan, 1996).

The correlation between consumers’ and trained panelists’ texture perception was studied by Cardello et al. (1982). The effect of training was mainly observed in trained panelists’ ability to differentiate between samples better according to their textural aspects compared with the consumers. This was explained as being caused by training broadening the perceptual range of textures. A difference in bread texture preferences was also observed. The texture preference evaluations of the trained panelists decreased more rapidly as a consequence of increasing elasticity and density than it did with the consumers. It was speculated that this was due to trained panelists’ ability to perceive a greater range of textural intensities than consumers. Thus, trained panelists should concentrate purely to intensity ratings, as it is shown that training affects their hedonic opinions (Cardello, 1982). Their ability to generate versatile picture of sensory properties of samples makes it easier to study attributes underlying consumers’ preferences.

Another statistical method enabling the study of which sample attributes guide consumers’ preferences is conjoint analysis. This method provides information on the relative importance of sample attributes and preferred levels of these attributes. The aim is to identify the attribute combination that provides the highest utility to consumers, i.e. determining the ideal product profile (Murphy et al., 2000). The method assumes that consumers evaluate the value (or preference) of a product by combining separate amounts of value provided by each product attribute. The use of conjoint analysis requires that the product attributes be varied based on a factorial design. Thus, the number of sample variations can easily become quite large. However, not all samples have to be evaluated by each subject, as a subset of all possible samples can be used in the actual evaluations (fractional design) (Hair et al., 1998). One advantage of conjoint analysis is that only the preference evaluations of consumers are needed. In external preference mapping, both descriptive analysis and consumers' preference evaluations are needed. However, the conjoint analysis method requires careful preplanning, since if an attribute is excluded from the research design, it is also not available for analysis (Hair et al., 1998). Conjoint analysis has traditionally been used in marketing research, but applications in the sensory evaluation field also exist (Vickers, 1993; Helgesen et al., 1998).

2.5.4 Texture sensitivity tests

Sometimes it is useful to know how sensitive people are to textural attributes of food. For instance, when members are selected to sensory panels it is worthwhile knowing how well they perceive changes in texture intensities overall. Furthermore, when consumers evaluate preference for texturally modified foods, the information on their texture sensitivity may serve as a good interpreter of preference differences. There are several ways to measure texture perception and texture sensitivity. The article of Fillion and Kilcast (2001) includes an extensive literature review of methods used to assess tactile and masticatory performance, i.e. ways to measure texture sensitivity. Texture sensitivity tests include tests than can be done in the mouth or by the hands (Johnson and Phillips, 1981; Fillion and Kilcast, 2001). Table 4 includes a selected list of texture sensitivity tests to provide an overview and examples of tests developed.

Table 4. Examples of texture sensitivity tests.

Type of test	Sample	Where tested	Reference
Two-point discrimination	0.5 mm steel pins with flat ends (single or in pairs, gap 0–1.0 mm)	Right index finger	Johnson and Phillips, 1981
Gap detection	30 mm diameter, 2-mm-thick plastic disk with gaps (0.2–2.0 mm)	"	
Grating resolution	25 mm square plastic blocks with gratings (1.0–5.0 mm)	"	
Letter recognition	26 capital letters in the English alphabet (3.0–8.0 mm high)	"	
Sharp vs. soft sensation	Cotton-tipped applicator and drafting compass needle	Anterior tongue and midpalate	Calhoun et al., 1992
Two-point discrimination	Two drafting calipers (gap from 1.0 mm until differentiated)	Left and right cheeks Midline of upper lip Midline of lower lip Midline anterior tongue Midpalate	
Tongue of the subject moved by examiner	Movements: 1 cm left, right up, down	Tongue	
Shape recognition	9 plastic shapes	In mouth	
Vibratory sensation	256-Hz tuning fork	Lower lip	
Temperature sensitivity	3-mm laryngeal mirrors, one at 5°C and another at 50°C	Anterior tongue Palate	
Size discrimination[2]	Powdered sugar grades presented in pairs (∅ 20–100x10^{-6} m and ∅ 650–900x10^{-6}m)	Tip of tongue	Fillion and Kilcast, 2001[1]
Oral shape recognition	5 capital icing sugar letters (A, P, O, S, H)	In mouth	
Chewing efficiency[2]	Two-colored chewing gum	In mouth	

[1] Only the most promising tests (according to the authors) are reported here.
[2] These tests were conducted in Study IV.

The standard texture rating scales, discussed above (Szczesniak et al., 1963; Munõz, 1986), also offer possible ways of screening panelists' texture sensitivity and ability to determine intensity changes in food texture attributes. In addition, the ASTM, the American Society for Testing and Material (1981), introduces three texture tests for screening panelists' suitability for a texture profile panel and for testing their ability to determine intensity changes in texture attributes. The first test concerns hardness perception and includes five food samples (Philadelphia brand cream cheese, Kraft American cheese, Durkee Exquisite giant-size olives, fresh carrots, Charms brand hard candy). The panelists are asked to rank the samples in order of increasing hardness. The second test concerns viscosity. Again, five food samples are introduced to panelists (water, heavy cream, maple syrup, Hershey brand chocolate syrup, and Magnolia brand sweetened condensed milk), and they are asked to rank the samples in order of increasing viscosity. The third test is a geometric test. Five food samples are presented to panelists (instant cream of wheat, canned chicken meat, dry-mix whipped topping, frozen haddock, and canned or dry-mix tapioca pudding), and they are asked to match each product with one appropriate geometrical descriptions: grainy, fibrous, aerated, flaky, or bready. Each test should be conducted three times. According to ASTM, the panelist who could be selected to a texture profile panel should rank or match at least 12 of 15 products correctly (five products times three replications). The ASTM further recommends that people using partial or full dentures should not be accepted into texture profile panels as dentures interfere with perception of at least some textural attributes. Problems in using this ASTM standard may arise because the standard is very American in its reference materials.

The validation of the texture sensitivity tests mentioned above is not good in all cases. The two-point discrimination, gap detection, and grating resolution tests, developed by Johnson and Phillips (1981), were tested only by trained subjects (number of subjects not reported). The letter recognition test was tested only with 14 subjects (Johnson and Phillips, 1981). In the texture sensitivity tests developed by Calhoun et al. (1992), a total of 60 subjects aged 20 to 80 years and over were used to test differentiation ability in texture tests. No further validation was reported. The tests by Fillion and Kilcast (2001), in contrast, were tested for both repeatability (number of respondents 2, 8-10 replications) and discrimination ability (number of respondents 151). International testing of these tests is underway in the European Commission Quality of Life Fifth Framework Programme QLK1-CT 1999-00010 (HealthSense). The standard rating scales developed by Sczcesniak et al. (1963) were tested on sensory–instrumental correlation (viscometer and texturometer), but the scales developed by Munõz (1986) were not. Furthermore, the ASTM does not report whether the texture sensitivity tests recommended were validated or not. Thus, when using texture sensitivity tests, attention should be paid to reliability of the test.

2.5.5 Instrumental methods

In addition to sensory measurement of texture, it is possible to measure texture by instrumental means. The demand for instrumental measurements is often rationalized with a need of cheap, efficient and objective measurements (Lawless and Heymann, 1998) and instrumental texture measurements are often developed with the aim of replacement of sensory measurements (Lawless and Heymann, 1998). Several statistically significant correlations are found in literature between sensory and instrumental measurements (e.g. Meullenet et al. 1997; 1998). Instrumental texture measurements can be divided into two categories: empirical tests and imitative tests. Empirical tests measure purely physical properties of foods while the imitative tests attempt to mimic actual eating situation, like mastication (Bourne, 1982). As instrumental methods were not used in Studies I-IV, only a very short overview of most general instrumental methods is included here.

There are several different types of empirical testing machines that use different techniques to measure food texture. Such instruments are for example penetrometers that measure penetrating material, the resistance of material towards penetration and/or the total depth of penetration, compressors that measure the ability of the material to resistance compressing force, viscometers that measure viscosity of the liquid or semisolid food products, and shearing devices that record force required to shearing the test material (Szczesniak, 1963; Bourne, 1982). Imitative texture tests are designed to mimic actual food processing like eating situation. One of the most known imitative tests is the food texturometer and the method called texture profile analysis (TPA). The TPA imitates the chewing action of the teeth. The main idea of the method is that approximately a bite-size piece of food is compressed two times in a row. As a result, a force-time curve is obtained. Several texture properties, like hardness, cohesiveness, viscosity, elasticity and brittleness, to mention a few, can be estimated from this curve (Szczesniak et al. 1963, Bourne, 1982). To make the TPA test more identical to actual chewing, lubrication between contact area of the sample and plates has been used. The lubricants (e.g. mineral of vegetable oil) are used for mimic fluids in the mouth (Pons and Fiszman, 1996). In addition, artificial dentures and tri-dimensional movements are adapted to TPA to make the method more realistic (Meullenet et al., 1997)

2.6 Summary

Food flavor and texture interact with each other during eating and they both affect food acceptability. It is often stated that flavor is more important than texture for overall acceptability of foods, but this is not the case in all food types or in all eating situations. Aging affects both food perception and food preferences. Physiological changes are likely to occur along aging and these changes alter flavor perception, especially through diminished olfactory function. Texture perception is also affected as a consequence of aging. Lacking of teeth, dentures and diminished muscle power may interfere chewing. These changes are most predominant when eating hard and tough foods. Furthermore, food and texture preferences change during life span. It has been noticed that, in addition to age, for example gender affects texture preferences. Thus, when an aged person eats certain food, the perception obtained from it is not similar as the perception obtained by a young person who eats the same food.

Food texture can be measured using either sensory methods or instrumental methods. Consumers are often asked only to evaluate liking of food samples or rate some “simple” food attributes, like hardness. Trained panelists may be used for evaluating qualitative and quantitative properties of difficult food attributes. Statistical methods can be used to combine these two types of data sets, and this provides an opportunity to examine which food attributes affect or even predict consumer preferences.

Thus, according to literature, aging affects flavor and texture perceptions and preferences. Therefore, which sensory attributes are the most critical for the food acceptance of the elderly? What happens to these preferences when food product is changed or its flavor and texture is manipulated? How flavor and texture properties of the food can be manipulated to provide foods that elderly find especially acceptable? Answers for these questions were searched in Studies I-IV included this thesis.

3 MATERIALS AND METHODS

3.1 General description of the studies

The present studies included four sensory studies (I-IV). Study I examined the effects of three thickeners and one thickener combination on sensory quality of high-viscosity gel samples, i.e. wine gum –type strawberry candies. Study II examined consumers' responses to the same samples used in the first study. The aim was to get an overview of consumers' texture preferences. The effect of age, gender, and previous experience was studied. Study III focused on the effects of processing conditions on sensory properties of muesli oat flakes. Consumers' responses towards the samples, together with the effects of age, dental condition, and previous use, were examined. Study IV investigated the relative importance of texture, taste, and aroma modifications on consumers' preference of a semisolid yogurt-type fermented oat bran product. The effects of age and previous use were studied. The aim of each study, the samples, and the subjects are presented in detail in Table 5. Only a general description of the experimental protocols carried out is given in this section. For more detailed information, see Studies I-IV in the appendix.

3.2 Subjects

The subjects were either trained sensory panelists or consumers. The trained sensory panels conducted descriptive analyses (I, III) or evaluated in advance predetermined sensory attributes of the samples (IV). The subjects of the trained sensory panels were either students or staff of the University of Helsinki, and all had earlier experience in sensory evaluation. The consumers were used for pleasantness evaluations. In addition, relative-to-ideal (i.e. just right) ratings of perceived texture and other sample attributes were evaluated. The consumers were recruited from the school class visiting the factory of the sample manufacturer (II), from the students and staff of the University of Helsinki (II, III, IV), and from the Kamppi Service Center for the Elderly (III, IV). See Table 5 for gender and age distributions.

3.3 Samples

Three types of samples were used in the studies: wine gum–type strawberry candies (I, II), muesli oat flakes (III), and fermented oat bran product (IV), which is a snack food–type semisolid product, similar to flavored yogurt or porridge. All samples were modified with regard to texture and flavor. The texture of the strawberry candies was modified using three different thickeners and one combination of two thickeners, and the flavor using two concentrations of strawberry aroma. The muesli oat flakes were modified using different processing parameters (two heat treatments and three thickness levels). In addition, two commercial oat flakes were used. The fermented oat bran products were modified with regard to texture (smooth or cooked oat grains added), taste (two sucrose concentrations), and aroma (two orange aroma concentrations). For more information on the samples, see Table 5. In addition, to test taste, odor, and texture perception, water solutions, vials containing odors, chewing-gum, and sugar crystals were used (see Study IV for more details and Table 4 for more information about texture perception tests).

3.4 Procedure

Study I consisted of a descriptive analysis of the high-viscosity gel samples conducted by a trained sensory panel. The panel training comprised of nine sessions, mostly involving evaluation exercises and group discussions with the aim of producing a consensus regarding the attributes evaluated. During the training commercial candies were used as reference materials to demonstrate the texture and flavor attributes discussed. Feedback of evaluation exercises was provided. The actual evaluations were conducted in a blind manner in partitioned evaluation booths in the sensory evaluation laboratory at the University of Helsinki.

Table 5. Aim of the studies and the samples and subjects used.

Study	Aim	Samples	Subjects
I	To define and quantify the most important texture and flavor variables of the high-viscosity gel samples made with different thickeners and aroma concentrations.	*High- viscosity gel samples, i.e. strawberry candies* (Leaf Oy, Finland), 8 types Thickeners: pectin, gelatin, starch, and a combination of gelatin and starch Strawberry aroma: 0.7 and 1.4 ml aroma/kg candy base	Trained sensory panel: (n=12, 2 M, 10 F, 26-49 years)
II	To study the texture preferences in different age groups by combining consumer evaluations and descriptive sensory profiles of trained panelists.	*High-viscosity gel samples, i.e. strawberry candies* (Leaf Oy, Finland), 4 types Thickeners: pectin, gelatin, starch, and a combination of gelatin and starch Strawberry aroma: 1.4 ml aroma/kg candy base	Consumer groups: Teenagers (n=60, 30 M, 30 F, 13-14 years) Young adults (n=60, 6 M, 54 F, 19-23 years) Middle-aged (n=60, 15 M, 45 F, 40-63 years)
III	To examine the effect of flake processing conditions on the sensory and hedonic quality of muesli oat flakes.	*Muesli oat flakes*, 8 types Six experimental flakes (factorial design): 2 heat treatments (with and without kiln drying), 3 thickness levels (Myllyn Paras Oy, Finland) Two commercial flakes: regular and organic (Oy Polar Mills Ab, Finland)	Trained sensory panel: (n=10, 1 M, 9 F, 24-54 years) Consumer groups: Young adults (n=45, 20 M, 25 F, 19-25 years) Adults (n=45, 16 M, 29 F, 35-49 years) Elderly (n=45, 16 M, 29 F, 58-85 years)
IV	To examine relative importance of texture, taste, and aroma on yogurt-type snack food for the elderly as compared with the young.	*Fermented oat bran product*, (Bioferme Oy, Finland), 2*2*2 factorial design, 8 types Orange aroma: 0.05% or 0.24% (w/w) Taste: 10% or 13.6% sucrose (w/w) Texture: smooth or 8% oat grains (w/w)	Trained sensory panel: (n=9, 2 M, 7 F, age 25-41 years) Consumer groups: Young adults (n=47, 11 M, 36 F, 20-35 years) Elderly (n=45, 4 M, 41 F, 65-82 years)

M=male; F=female

Study II was a consumer study. The consumers rated hardness, adhesiveness, and fracturability of the samples using a relative-to-ideal scale. Pleasantness of the samples was evaluated using a hedonic scale. The samples were blind evaluated. The youngest age group evaluated the samples in the canteen of the sample manufacturer. The other two groups evaluated the samples in partitioned evaluation booths at the University of Helsinki. Background information on age, gender, and reported use frequencies, together with reported pleasantness evaluations of ten commercial candies, were collected.

In Study III both descriptive analysis and consumer tests were used. Training of the sensory panel consisted of nine training sessions, including group discussions and evaluation exercises. Again, reference materials were used to demonstrate and to practice attributes evaluated. Feedback on the exercises was provided. Actual evaluations were conducted in a similar fashion as in Study I. Consumer testing included three age groups. The two youngest groups evaluated the samples at the University, while the eldest group conducted the evaluations at the canteen of the Kamppi Service Center for the Elderly. Only pleasantness of the samples was assessed. Background information on age, gender, dental condition, and use frequency of muesli was collected.

In Study IV a trained sensory panel was used at the pretesting phase to determine the aroma and sucrose concentrations of the samples. The aroma and sucrose concentrations were selected so that the perceived increases in odor and taste intensities were equal. This was achieved by using the magnitude estimation method and a plot of log concentration vs. log perceived intensity (Stevens' power function, e.g. Lawless and Heymann, 1998). The same panel also determined the amount of cooked oat seeds to be added to the lumpy version of the samples and evaluated the sensory properties of the final products. The attributes to be evaluated were determined in advance by three experienced sensory panelists and were selected on the basis of their ability to differentiate and describe the sensory properties of the samples. Two consumer groups evaluated overall pleasantness and pleasantness of texture using hedonic scales, and odor and flavor intensity using relative-to-ideal scales. The taste, odor and texture sensitivity tests were conducted in separate session. All consumer evaluations were conducted at the University.

3.5 Data analysis

The statistical methods used in Studies I-IV are presented in Table 6.

Table 6. Statistical methods used in Studies I-IV.

Study	Statistical method used to analyze the result of:		
	Trained sensory panel	Consumers	Both (combining results)
I	Analysis of variance Principal component analysis		
II		Analysis of variance Principal component analysis	PrefMaX[1] t-test
III	Analysis of variance		Partial least squares regression
IV	Analysis of variance	Principal component analysis Conjoint analysis	

[1] For more information on the method, see Study II.

In Study I, differences between texture and flavor properties produced by different thickeners were evaluated. In Study II, the aim was to combine consumer evaluations and descriptive sensory profiles obtained from Study I. The effects of sample attributes on consumer preferences were assessed. In addition, the effect of consumers' background (age, gender, reported use frequency, and reported liking of commercial candies) on sample preference was studied. The statistical method PrefMaX, developed by Dr. Schlich, was used in Study II because it enables the use of fewer samples than traditional external preference mapping, such as partial least squares regression. The second article does not introduce the method, but it was tested in this article with four samples. The consumer evaluations were also analyzed with more traditional methods, and these findings were compared with those of PrefMaX. In Study III, the effects of processing conditions on the sample attributes were investigated. The results of the trained sensory panel and consumers' preference evaluations were combined, and the attributes predicting consumers' preference were assessed. Furthermore, the effect of age, use frequency of muesli products, and the effect the elderly consumers' dental condition on preference evaluations were assessed. In Study IV the influence of texture, taste, and aroma modifications on sensory properties of fermented oat bran product and consumers' preference evaluations were assessed. The effects of age and use frequency of yogurt on preference evaluations were also studied. The conjoint analysis enabled examination of the relative importance of texture, taste, and aroma on preference evaluations (Hair et al., 1998). The power of the taste, odor and texture sensitivity tests to predict elderly consumer responses towards fermented oat bran product samples were studied and the difference between the young and the elderly on texture tests was assessed.

4 RESULTS

4.1 Effect of food components and processing on perceived texture and flavor

The high-viscosity gel samples demonstrated that the type of thickener strongly affects perceived texture and flavor of gels. Each thickener used produced its own characteristic texture, and each texture had specific flavor release properties (I: figs 1-3). The study indicated that a rapid breakdown rate of the gel minimizes its flavor-masking effect. The gels with weak and fragile texture allowed flavor be released strongly and quickly, while gels with cohesive texture held the flavor more tightly. Thus, food components affected texture characteristics and flavor perception, probably through different flavor release properties.

Different textures and flavors can also be produced by modifying processing conditions, as demonstrated in Study III. High-heat treatment (kiln drying) produced sweeter flakes that absorbed less milk than flakes made with mild-heat treatment, without kiln drying. Thickness, another processing parameter varied, had several effects on texture and overall taste intensity of the flakes. Thickness affected milk absorption capacity, fragility, and amount of mastication needed (III: figs 1-3). With regard to taste properties, the thinnest flakes had a weaker taste than thicker ones when tasted with milk (III: figs 2-3).

In Study IV, the texture of the samples was modified by adding cooked oat grains into fermented oat bran product. The grain addition did not have any main effects on shortness or firmness of the samples, which were the only texture attributes evaluated. However, sucrose concentration did affect texture. The samples with high sucrose concentration were less splitting and less firm than the ones with low sucrose concentration. Interactions between texture (lumpy vs. smooth) and taste (sucrose concentration) revealed that these changes were more pronounced in smooth than in lumpy samples. Sucrose concentration, together with aroma concentration, had several effects on sample flavor and odor attributes, e.g. an increase in sucrose concentration increased sweetness as expected, but also total flavor intensity, while an increase in orange aroma concentration increased odor and total flavor intensities (IV: tab 2).

4.2 Effect of age and previous experience on preference evaluations

Age affected texture preferences of the samples used in Studies II-IV. The eldest age group differed from the younger groups in each of the three studies. Their flavor and, in particular, texture preferences, differed from those of younger consumers. While Studies II and III indicated that the eldest consumers were more precise about texture requirements than their younger counterparts (II: fig 5, tab 2; III: figs 2-3), Study IV revealed that the eldest consumers were willing nevertheless to accept textural variety in the samples (IV: fig 1, tab 3).

In Study II, both age and gender affected texture preferences. The eldest consumers were clearly divided into different sample (texture) preference groups (II: tab 2). For example, the texture preferred by middle-aged females was short and fracturing (pectin), while middle-aged males preferred harder and more adhesive candy texture (starch). However, these gender differences must be interpreted with caution as the gender distribution of the eldest consumer group was uneven and the number of subjects was rather low. The numbers of members in the two youngest consumer groups stayed relatively constant from one preference group to another. Thus, sample (texture) preferences did not differ in these age groups.

Elderly consumers' texture preferences differing from those of younger consumers were also demonstrated in the study on muesli oat flakes (III). In general, consumers preferred fragile, flakes that absorbed relatively large amounts of milk and did not need extensive mastication. For the elderly, the demand for an easy eating experience was predominant. Especially lack of adhesion to the teeth during eating, strong milk absorption capacity, a small amount of mastication, and fragile texture were considered critical attributes for flake preference. Mild flavor was also preferred overall (III: figs 2-3).

Differences between the elderly and the young consumers' texture preferences were also observed in the study with fermented oat bran product samples (IV). The texture of the samples was modified by adding cooked oat grains to a traditionally smooth product. When the texture was manipulated, the texture pleasantness evaluations of the younger group decreased remarkably, while the evaluations of the elderly remained statistically unchanged (IV: fig 1). Moreover, the relative importance of texture differed from one age group to another, as the young considered texture more important than did the elderly (IV: tab 3).

Some evidence was also found that previous experience might affect hedonic evaluations of different textures, at least in the case of candies. In Study II, the background questionnaire provided information on reported use frequencies and reported liking of ten commercial candies. These commercial candies included four candies the textures of which were similar to those of the samples. In some cases (two of four), the reported dislike of commercial candy having sample-like texture also occurred in the sensory evaluation of that particular sample (II: figs 3, 5, tab 2). In addition, the internal preference mapping of the age groups and reported liking of the ten commercial candies showed that the eldest consumers stated liking the commercial pectin-type candy more than the younger age groups (II: fig 3). The results indicated that the consumers belonging to the pectin sample preference group were mostly middle-aged, and more precisely, middle-aged females (II: tab 2).

The reported use frequency of four commercial candies the textures of which were similar to those of the samples had no effect on liking of the samples (II: fig 2, tab 2). In the case of muesli oat flakes (III), the reported use frequency of muesli products had no effect on preference evaluations given to muesli oat flake samples. A similar result was obtained in the fermented oat bran product study (IV), where use frequency of yogurt was used to predict preference evaluations given to the samples. The reported use frequency of yogurt was used to predict pleasantness evaluations of the fermented oat bran product because of the similarity between the product and yogurt, which was especially pronounced in the case of texture. The fermented oat bran product is also relatively unknown, and a great majority of the elderly stated never heard or tasted the product before.

4.3 Relative importance of texture, taste, and aroma

Study IV examined the relative importance of texture, taste, and aroma on overall pleasantness evaluations of the fermented oat bran product. The young and the elderly differed according to perceived importance of these factors (IV: tab 3). For the young, aroma was by far the most dominating factor, contributing 80.1% to overall pleasantness. Low aroma concentration was preferred. The relative importance of taste was low (only 7.6% in the young group), and low sucrose concentration was preferred. The elderly paid an equal amount of attention to aroma and taste (47.1% and 45.7%, respectively), and preferred low aroma and high sucrose concentrations. Texture had a relatively minor impact on pleasantness of oat bran product samples. For the young, texture was slightly more important as compared with the elderly (factor importance 12.3% and 7.2%, respectively). The main results of Studies I-IV are summarized in Table 7.

4.4 Sensitivity tests

The prediction power of the sensitivity tests was present only in few cases. The elderly who were more sensitive to sour taste evaluated the relative-to-ideal flavor of the samples as ‘too strong’ and further from ‘just-right’ than the elderly with poorer sourness sensitivity scores. In addition, the elderly with fewer olfactory test scores evaluated the overall pleasantness of the samples higher in comparison with those having better odor perception scores (IV: tab 4). When the results of the elderly in texture tests were compared with the young, no difference was obtained in their ability to detect differences in sugar crystal size (IV: fig 3). However, the young outperformed the elderly in the chewing efficiency test (IV: fig 4).

Table 7. Main results of Studies I-IV.

Food sample (No. of samples)	Varied attributes	Attribute categories evaluated [1]	Examples of preferred attributes	Factors affecting consumer segmentation	Most important attribute predicting preference	Reference
High-viscosity gel samples, i.e. strawberry candies (4)	Thickener, aroma concentration	F, T	Strong taste intensity (F), adhesive, elastic (T) [2]	Age (gender, previous experience [3])	Texture	Kälviäinen et al., 2000 (I) Kälviäinen et al., 2000 (II)
Muesli oat flakes (8)	Heat treatment, thickness, manufacturer	O, F, T	Roasted (O), mild taste (F), fragility, milk absorption (T) [2]	Age, dental condition	Texture	Kälviäinen et al., 2002 (III)
Fermented oat bran product (9)	Aroma, sucrose concentration, texture	O, F, T	Sweetness, low flavor intensity (F), smooth (T) [2]	Age	Flavor	Kälviäinen et al., In press (IV)

[1] A = appearance, O = odor/aroma, F = flavor, T = texture
[2] The most preferred attributes depend on the consumer segment.
[3] The study serves as an example of possible segmentation, no final conclusions should be made on the basis of the study.

5 DISCUSSION

Texture and flavor properties of semisolid and solid foods and their impact on consumer responses were studied using both trained sensory panels and consumers. Three sample materials were used (high-viscosity gels, muesli oat flakes, and yogurt-type fermented oat bran product). The studies provided information on how texture and flavor manipulations affect food attributes and how these changes influence consumers' preference evaluations. Different consumer age groups were studied. In addition, the studies provided information on the relative importance of texture, taste, and aroma in the semisolid and solid food samples.

5.1 Review of method

The subjects participating in the studies were obtained from three places: the University of Helsinki, the Kamppi Service Center for the Elderly, and a school class visiting the sample manufacturer. The use of University students and staff obviously narrows the generalizability of the results as people studying or working at the University can be assumed to differ from the general population of Helsinki and Finland. In addition, some of the University respondents studied or worked in the food area, and thus, might differ from those working in nonfood areas. All elderly subjects were healthy and living independently in Helsinki. These people therefore did most of their own grocery shopping and were responsible for their eating decisions. They may also differ from the elderly population living outside Helsinki. Despite these limitations, the results are reliable indicators for describing trends in consumers' preferences.

The age range of the oldest age groups in Studies II-IV varied from study to study. In Study II, the consumers belonging to the oldest age group were younger (40-63 years) than the oldest consumers in Studies III and IV. The oldest age group used in Study I was considered being perhaps a bit too young when studying the effect of aging on sensory perception. Therefore, slightly older age groups were recruited in Studies III and IV, and the age range varied from 58 to 85 years, and from 65 to 82 years, respectively. It is likely that variation in sensory perception occur also within these age groups, and the differences between age ranges may limit the interpretation of the results. However, when compared to the younger age groups, clear differences in sensory perception were obtained.

Most of the sensory testing took place in the sensory evaluation laboratory at the University, where separate evaluation booths were available. However, one group of teenagers evaluated samples in the canteen of the sample manufacturer, and one group of elderly persons in the canteen of the Kamppi Service Center for the Elderly. In these cases, special attention was paid to ensure that subjects conducted their evaluations individually, avoiding unnecessary contact with other subjects.

In sample preparation, it is not always possible to produce samples such that only one food component is changed while the other components remain unchanged. This was also the case in all of the studies. The texture of the high-viscosity gel samples was varied using three thickeners and a combination of two thickeners. Because the amount of thickeners was changed from one sample to another to produce realistic candies (variation from pectin 1.7% w/w to starch 15.8% w/w), producing samples that would have been identical with the only exception of the type of thickener was not possible. This, together with two aroma concentrations used, led into differences in ingredient concentrations. Pectin candies were also covered with sugar crystals. This was necessary to avoid samples adhering to the production line. This sucrose cover could have affected flavor release properties of the samples in Study I. When samples were put into the mouth and initial flavor intensity was evaluated, the sugar crystals may have heightened perceived flavor intensity. Differences in sucrose concentration, availability of sucrose for perception, thickener concentration and type of thickeners were present in high viscosity gel samples. All these together with possible taste-aroma interactions influenced perception of overall flavor intensity (Frank and Byram, 1988; Frank et al., 1989; Cliff and Noble, 1990; Noble, 1996; Godshall, 1997; Stevenson et al., 1999). The slopes indicating flavor release differ from one sample type to another. Thus, it is reasonable to assume that differences in flavor release did occur. With muesli oat flakes, the samples manufactured with the factorial design were all of the same variety. However, the variety of commercial samples differed from that of experimental samples. Ingredient concentrations were also modified in fermented oat bran products. To avoid unnecessary differences, sucrose and aroma additions were made to jam such that the total amount of jam maintained the same (20%) in all samples. Grain addition (8%) to oat bran (80%) of the final products was carried out similarly. As in the case of high viscosity gel samples, the differences in sucrose concentration and its availability for perception produced by other sample ingredients, as well as taste-aroma interactions, may have influenced perception of flavor and aroma of fermented oat bran products during consumption. Nevertheless, in all studies, care was taken to avoid unnecessary differences in samples.

From the methodological point of view, the main idea was to study consumer responses to samples in which texture and flavor had been modified. This was done using statistical methods, such as PrefMaX, external preference mapping, and conjoint analysis. The PrefMaX was used in Study II, because aroma levels used in the high viscosity gel samples of Study I were not sufficiently different to produce sensory variation in flavor properties. Thus, only four different samples instead of eight were available, whereas the absolute number of samples required for preference mapping is six (McEwan, 1999). The PrefMaX method gives relatively similar results to the traditional preference mapping. These two methods can be used when studying which product attributes explain consumer preferences. Conjoint analysis provides information of relative importance of product attributes (in this case: texture, taste, and aroma). The importance of these attributes is assessed based on consumers' preference evaluations.

The statistical methods used enable determination of which product attributes explain consumer preferences. The methods also help to examine the importance of attributes governing consumer preferences (Greenhoff and MacFie; 1994, McEwan, 1996; Hair et al., 1998). The use of preference mapping includes descriptive analysis, where the attributes evaluated by the descriptive panel are chosen by the criteria that they be important for sensory quality of the samples and that they also differentiate the samples (Civille and Lawless, 1986). In conjoint analysis, the attributes included are decided in advance by the researcher. Frequently, it is not easy to know which attributes are important in the final samples. This is one reason why fewer attributes are often included in conjoint analysis as compared with preference mapping. Even though preference mapping may use more attributes than conjoint analysis, one cannot be certain whether all the attributes included are similarly noticed by the consumers. The question to which attributes consumers focus when evaluating preference remains unanswered (Moskowitz and Krieger, 1995), and it is not sure, whether all attributes are even noticed by the consumers (Jeager et al., 2000). Unlike preference mapping, conjoint analysis also enables the effect of abstract product attributes, such as information and prices to be examined (Hair et al., 1998).

When the preferences of consumers are studied with the help of a trained sensory panel or by calculating factor importance from consumers' preference evaluations, the answers obtained always include sources of error. Thus, is it possible to ask consumers to rate sample attributes directly? Fillion and Kilcast (2002) did observe that free choice texture profiles of consumers and trained panelists were similar, even though consumers' vocabulary to describe texture attributes was limited when compared with trained panelists. Furthermore, the sensory profiles given by consumers where shown to be discriminant (Husson et al., 2001). If a group of consumers was familiarized briefly with food attributes and evaluation techniques without extensive training, would they still maintain a consumer-like way of thinking? If the attributes included in the study could be decided in advance by researchers or selected on the basis of pretesting, as in consumer interviews, unnecessary training could be avoided. Of course, the use of consumers' sensory profiles does not eliminate the need for trained sensory panel profiles since the consumer profiles probably include less accurate descriptions than profiles by trained panels. However, they can yield some basic features and are, therefore, useful (Husson et al., 2001).

All the consumer preference tests used in our studies were sensory tests. The consumers were asked to taste the samples and provide their evaluations on a questionnaire. Whether single taste tests can predict actual eating and preference behavior is questionable. Vickers and Holton (1998) found that taste tests failed to predict actual consumption during a two-month test period. Furthermore, Vickers et al. (2001) reported differences in taste test preference ratings and lunch situation preference ratings. However, taste tests are a common sensory practice and their ability to predict actual preference is widely accepted, although results of the taste tests should not be interpreted as the one and only truth (Lucas and Bellisle, 1987).

One aim of the studies was to obtain information on how age, gender and previous use predict consumer preferences. An attempt was made to obtain consumer groups with similar numbers of males and females. However, in the elderly population, there were considerably fewer males available and they were less willing to participate in sensory tests than females. The gender distribution was also relatively unbalanced among students and staff of the University, leading to a smaller proportion of males in the consumer groups recruited from the University. This resulted in the effect of gender on consumer preferences only being examined in one study.

5.2 Effect of food components and processing on perceived texture and flavor

5.2.1 Thickeners

Study I demonstrated that each thickener and one combination of two thickeners produced characteristic textures with specific flavor release properties. The texture characterizations obtained were highly similar to those found in the literature. According to Smewing (1999) and Study I, pectin gels are soft, inelastic, and have short texture. Pectin forms gels at high sugar concentrations, which makes it very suitable for candy manufacturing (Alexander, 1999). Gelatin gels are soft, elastic, vibrant, and they melt in the mouth, providing excellent 'mouthfeel' and flavor perception. Gelatin does not produce any color of its own, thus the gels are clear and colorless without added colorant. Starch forms short gels with heavy-bodied 'mouthfeel' and milky-white appearance (Smewing, 1999). When comparing the gels to each other, our findings are congruent with the results of Marshall and Vaisey (1972), who described the pectin gel as less cohesive, less springy, less chewy, and less gummy as compared with gelatin and starch gels. In addition to gels made with single thickeners, mixed-gel systems enable production of a wide range of textures that can be specially designed for particular purposes (Smewing, 1999).

According to literature, gel texture affects aroma (evaluated by sniffing) and taste (evaluated in mouth) release. Weak gels release aroma more strongly than firm, cohesive ones, and the type and concentration of volatile compounds have effect on aroma release (Jaime et al., 1993). The type of aroma added to gels and its concentration do not affect perceived texture of the samples (Jaime et al., 1993). In taste release, Marshall and Vaisey (1972) demonstrated that gels with less cohesive, less elastic, less gummy, and less chewy texture tasted sweeter than firmer gels, even though their sucrose concentrations were similar. Thus, the type of thickener, the type of taste and aroma compounds, and their interactions, affect textural properties as well as taste, and aroma release of gels (Noble, 1996; Godshall, 1997).

The study on high-viscosity gel samples demonstrated that the texture of the gels had a strong impact on overall flavor release, which was evaluated as a combined sensation of taste and aroma perceived in the mouth. For example, by mixing gelatin and starch, the texture and flavor release properties obtained were an intermediate form of pure gelatin and pure starch gels. In general, the fragile, weak gels released flavor quickly and forcefully, while the firm, cohesive gels held onto their flavor more tightly. These results are in agreement with earlier findings that different in-mouth breakdown rates are mainly responsible for flavor release from gels (Wilson and Brown, 1997; Baek et al., 1999). Cohesive gels also have prolonged total flavor perception time as compared with less cohesive gels (Guinard and Marty, 1995; Wilson and Brown, 1997). Texture of the gels can be manipulated also using other ingredients than thickeners. Pålsgård and Dijksterhuis (2000) studied the effect of pH and NaCl modifications on flavored gels and observed that pH had strong effects on gel texture and flavor release (evaluated in mouth), while NaCl had marginal effects on flavor.

5.2.2 Other food components

The study on fermented oat bran product samples (IV) demonstrated that the concentration of sucrose affected textural properties of the samples. Increased sucrose concentration (from 10% to 13.6% w/w) decreased shortness and firmness of the samples. Thus, the viscosity of the samples seemed to decrease with sucrose addition. These changes were pronounced in the smooth oat bran product. The earlier studies exploring the effect of sucrose on texture of semisolid products give relatively mixed results. Theunissen and Kroeze (1995) reported two sets of results. In the first experiment, the addition of sucrose (from 5.2% to 15.4% w/w) decreased perceived viscosity of the carboxymethylcellulose solutions. No such decrease was observed in the second experiment, with similar types of samples (sucrose concentration from 5.2% to 34.2% w/w). It was suggested that the possible viscosity decrease caused by sucrose addition remained unidentified in the second study because the samples were presented at three different viscosity levels. The authors concluded that the subjects might have concentrated only on differentiating these three viscosity levels, paying no attention to the smaller differences caused by sucrose concentration. The study on yogurt samples indicated that instrumentally measured viscosity increased when the portion of sucrose increased (from 2% to 10%), and the portions of xylitol or sorbitol decreased (Hyvönen and Slotte, 1983). In another yogurt study, an increase in sucrose concentration (from 6% to 10% w/w) decreased sensory thickness of samples (Koskinen et al., submitted). Thus, the effect of sucrose on food texture seems to be concentration- and food-dependent. The moment of sucrose addition may also affect the direction of changes.

With regard to taste and flavor properties, sucrose addition increased sweetness and total flavor intensity of the fermented oat bran product. The effect of increasing sucrose concentration on perceived sweetness and flavor intensity has previously been demonstrated, for example in yogurt samples (Wilson et al., 1993; Fernández-García et al., 1998; Drake et al., 2001). Orange aroma addition increased orange odor, orange taste intensity, and total flavor intensity, but it did not enhance sweetness. The effect of orange aroma on taste was also shown in Nahon et al. (1998), where orange aroma addition to water solutions increased orange taste, while not affecting sweetness. The addition of cooked oat grains to oat bran product samples had only minor effects on perceived texture and no effect on sample flavor. The grain addition perhaps did not affect flavor because both the grains and the fermented sample base itself were made of oat. The only influence of added grains, besides lumpiness, which was not rated, was that the effects of sucrose addition on firmness and shortness were less pronounced in lumpy samples.

5.2.3 Processing conditions

The study on muesli oat flakes (III) demonstrated that changes in processing parameters produce different texture and flavor properties. Kiln drying, which was the high heat treatment used in this study, is traditionally used to stabilize oat products against development of enzymatic rancidity and to achieve a long shelf-life. It also destroys unwanted bacteria and fungi, and produces a pleasant, oaty aroma and nut-like flavor (Ganssmann and Vorwerck, 1995). In Study III, kiln dried flakes gave a more intense sweet taste and a lower milk absorption capacity when compared with flakes made without kiln drying. Another processing parameter manipulated, i.e. thickness, had several effects on texture and flavor properties of the samples. Thickness of the flakes is usually determined by the purpose of the use. Study III indicated that consumers prefer relatively thin flakes. However, the flakes required for muesli are traditionally quite thick to ensure that they remain intact or do not produce too much flour in the muesli packages (Ganssmann and Vorwerck, 1995). Thus, a compromise is needed to fulfill both the consumers' hedonic and the muesli manufacturers' technical requirements. The processing parameters offer a possible way of modifying sensory properties of food products without changing food components. This was also demonstrated by Faller et al. (1998), who studied the effects of sugar level and initial moisture content on extruded corn-soy breakfast cereals. All in all, processing conditions are extremely important for the overall quality of the final oat product. Thus, to produce "good" oat products, several processing parameters must be considered and optimized (Ganssmann and Vorwerk, 1995; Faller et al., 1998; Oksman-Caldentey et al., 1999).

5.3 Effect of age and previous experience on preference evaluations

5.3.1 Age

Preference mapping studies have demonstrated that age affects consumer food preferences (see Table 2). Age has been found to affect food preferences in several earlier studies (Helgesen et al., 1997; Hough and Sánches, 1998; Murray and Delahunty, 2000; Richardson-Harman et al., 2000) as well as in Studies II–IV. Even though the age range of the oldest age groups varied from Study II to Study IV, the effect of aging was clearly present in each case. In the case of high-viscosity gel samples, the oldest consumers (40-63 years) were more segmented into candy preference groups than teenagers (13-14 years) and adults (19-23 years). Thus, the younger adult consumers were willing to accept a wide range of candy textures, while the middle-aged were very precise about the types of textures preferred. Young teenagers' tendencies to accept a broader range of sweet product variations was also observed by Hough and Sánches (1998), who studied cocoa milk products. They reported that although the ideal cocoa milk product for children (11-12 years) was similar to that of young adults (18-22 years), children preferred wider range of cocoa drinks than the young adults.

The effect of age on texture preferences was also present with muesli oat flakes. The most important factor predicting consumers' preferences was texture. An easy eating experience was preferred and textural requirements were especially pronounced in elderly consumers (58-85 years). The elderly perceived as particularly important that the flakes did not adhere to teeth during eating, were fragile, had strong milk absorption capacity, and needed only a small amount of mastication. Peleg (1993) stated that foods requiring large amounts of mastication, large forces to break down, and foods that adhere are problematic for the elderly. This statement was supported by the findings in Study III.

Another age-related factor, dental condition, was found to have some effects on elderly consumers' texture preferences. Even though the number of respondents in dental groups in Study III were not matched, the results suggest that elderly persons with dental defects have more exact textural requirements for muesli oat flakes than those with no missing teeth or no dentures. The differences were most marked in requirements for fragility, adhesiveness, minimal mastication, and maximal milk absorption capacity. These results are in accord with earlier studies, indicating that denture-wearing is related to the ability to eat foods requiring greater chewing effort (Horton, 1987; Smithers et al., 1998; Wynne, 1999).

In addition to dentures interfering with texture perceptions, they are known to have other food perception–related disadvantages. According to Duffy et al. (1999), dentures interfere with flavor perception. Their study on 65- to 93-year-old women showed that subjects using dentures that cover the palate had significantly higher flavor thresholds than those wearing dentures that left the palate exposed. However, in Study III, dentures were mostly found to affect texture perception.

The difference between texture preferences of the young (20-35 years) and the elderly (65-85 years) was also present in the study on fermented oat bran product samples. The grain addition to the samples did not decrease texture pleasantness evaluations of the elderly, as it did with the young. The grains had a relatively smooth texture, and therefore should not have been too problematic to eat for the elderly. Horton (1987) stated that although aging causes difficulties in eating certain foods, the elderly still want to experience textural variety. This may be one explanation why the elderly liked both smooth and lumpy sample textures almost equally well. The reason why the young liked the smooth texture more than the lumpy one may be partly because of previous experiences (discussed later).

Besides texture preferences, age affected flavor preferences. Most of the oldest consumers preferred high-viscosity gel samples with a relatively weak and fracturing texture. The flavor release of these samples was more intense than that of other samples. This may indicate a preference for high flavor concentration among the aged in Study II, a result also reported in earlier studies (de Graaf et al. 1994; de Graaf et al. 1996; de Jong et al. 1996). A contrary finding was found in the study with muesli oat flakes, where mild taste was preferred by all age groups. It is known that when the flavor of food is relatively bland, texture becomes increasingly important (Szczesniak, 1971). This was also the case in the flake study, where texture was the most important attribute predicting flake preference. Thus, mild flavors may also appeal to the elderly. When this does happen, however, a greater demand is placed on other food attributes, such as texture. Furthermore, in actual eating situations muesli contains ingredients other than flakes, such as nuts and dried fruits, which together produce variable flavor sensations (Payne, 1987). According to Hyde and Witherly (1993), people tend to desire combinations in such foods as in salads, sandwiches, and tacos: therefore, why not in mueslies as well. Mild-tasting components may even increase the total pleasantness of the multi-component food product, where other particles serve as a source of intense flavor.

The difference between the flavor preferences of the young and the elderly also manifested in the oat bran product study, where the elderly evaluated the appropriateness of oat bran products' odor and flavor as weaker and closer to the "just-right" than did the young. The main reason for differences between the odor and flavor evaluations of the young and the elderly might be due to impaired olfactory and taste functions of the latter group. Age-related olfactory weakening is present in both odor discrimination and identification ability. Taste perception is also affected but to a lesser extent than olfaction. Losses in taste sensitivity are taste-specific. (Stevens and Dadarwala, 1993; Stevens et al., 1984; 1995; Stevens and Cain, 1985; 1986; 1987; 1993; Bartoshuk et al., 1986; Chauhan et al. 1987; Cowart, 1989; Murphy, 1993; Lehrner, et al., 1999; Kaneda et al., 2000; Mojet et al., 2001).

Study IV indicated that aroma levels used in the samples were too high. Apparently, the elderly perceived the flavor of the oat bran product as being weaker than did the young, therefore giving higher pleasantness scores to the samples. This result is fairly congruent with earlier studies indicating that the elderly tend to prefer stronger flavor concentrations than younger consumers (Schiffman and Warwick, 1993; de Graaf et al., 1994; 1996; de Jong et al., 1996; Griep et al., 1997; 2000; Zandstra and de Graaf, 1998). It should be noticed that the earlier studies mostly deal with flavor enhancement rather than adding single aroma concentration, which was the case in Study IV. It is likely that the elderly need stronger flavor concentrations to perceive similar intensities to the young because of impaired olfactory function, and this may be the reason why amplified flavors may be preferred in general. When the aroma concentration of the samples was increased, the just-right flavor ratings of the young increased more steeply than those of the elderly. Similar observations in concentration-intensity functions have been made in earlier studies (de Graaf et al., 1994; 1996). In addition to amplified flavor preference, the elderly preferred the oat bran product samples with high sucrose concentrations, while the young preferred samples with low sucrose concentration. Findings of previous studies (e.g. Chauhan et al., 1987) indicate that the ability to detect sweet stimuli does not weaken with age. As perception of other taste qualities seems to weaken, the elderly may pay more attention to sweetness than to other taste qualities and may judge products based on this. Earlier studies on chocolate custard and orange beverage samples have also indicated that the elderly tend to prefer higher sweetness levels than the young (de Graaf et al., 1996; Zandstra and de Graaf, 1998).

Thus, age influences both texture and flavor preferences. It seems that the aged are more precise with their texture requirements than the young. The ease of eating is their number one priority, but when this criterion is fulfilled they are willing to accept textural variety in products. With regard to flavor, amplified flavors are generally preferred by the aged. However, mild flavors may also be acceptable in certain food products, in which case heightened requirements are placed on other sensory characteristics. Textural requirement, for instance, may be pronounced.

5.3.2 Previous experience

In the case of high-viscosity gel samples (I), the background information showed that young consumers, especially the teenagers (13-14 years), more frequently used and rated the liking of commercial candies higher than did the middle-aged (40-63 years). This suggests that the candies were likely more familiar to younger consumers. Thus, familiarity may more easily evoke young consumers' acceptance to a wide range of candy textures. The two youngest consumer groups being almost evenly segmented in each sample preference group supports this assumption. Middle-aged consumers indicated using and liking the commercial pectin-type candy more than younger consumers, and middle-aged females (45 of 60 respondents) formed the majority of the pectin sample preference group. Thus, it seems that at least in the case of candy texture, previous experience guides preference evaluations in tasting situations.

The use frequency of muesli products had no effect on consumers' preference evaluations of the flakes, which actually are only one part of the traditional muesli. Thus, the use frequency of the complete muesli does not predict the preference of a single food component (oat flakes). Oat flakes are relatively mild-tasting muesli component when compared with raisins and dried fruits (Payne, 1987). Williams et al. (1982), who studied the relative acceptability of apple slices in different models of presentation, stated that the sensory properties of a single food component (apple slices) become less important as the dish become more complex. It is assumed that this was also the case in the flake study.

With regard to the oat bran product samples (IV), yogurt was used to study the effect of previous experience on sample preferences because of the similarity between oat bran products and yogurt, which was especially remarkable in the case of texture. Oat bran samples were also relatively unknown, so that none of the elderly and only a few of the young were already familiar with the samples. The young consumed yogurt considerably more often than the elderly, and their texture pleasantness evaluations decreased as a consequence of grain addition, while the texture pleasantness evaluations of the elderly remained unchanged. As traditional Finnish yogurts have smooth texture, the grains added to oat bran products might have served as disruptive components and deviation from the familiar experience for the young. Previous texture preferences are known to affect hedonic ratings within food categories (peas) (Baron and Penfield, 1993), and when the texture of the food is different than expected, the food is easily rejected (Szczesniak and Khan, 1971). These findings were confirmed in Study IV.

The studies demonstrated that age and previous experiences with sample-like products affect consumers' preference evaluations. A slight effect of gender was also observed. Thus, when the results of consumer preference test are interpreted, consumers should not be treated as a homogeneous group. Special preferences, if not demands, are formed as a consequence of aging. As the elderly are a growing consumer segment world-wide (Jellinek, 1989; Dichter, 1992), their needs and desires must be taken into account in product development.

5.4 Relative importance of texture, taste, and aroma

According to the literature (see Table 2), the most important product factor affecting consumers' preference evaluations is food-dependent. However, in most cases, flavor holds the number one position. With fermented oat bran products, aroma is very important for the overall pleasantness of the samples; the consumers did separate the samples according to aroma concentration. The main reason for the strong effect of aroma on overall pleasantness was probably caused by its strong impact on perceived flavor. Both age groups preferred low aroma concentrations and the pleasantness evaluations decreased with increased aroma concentration in both age groups, although the decrease was smaller in the elderly. As discussed above, the elderly tend to like foods in which the flavor has been enhanced (de Graaf et al. 1994; 1996, de Jong et al. 1996). This gives us a reason to believe that the aroma concentrations used in Study IV were too high. An increase in aroma concentration only, instead of flavor enhancement with wider variety of aroma and taste compounds, obviously did not produce palatable enough changes in overall pleasantness. Taste is another important attribute influencing elderly consumers' pleasantness evaluations, and high sucrose concentration was preferred. The finding is consistent with earlier literature indicating that elderly like sweeter foods than do the young (de Graaf et al., 1996; de Jong et al., 1996; Zandstra and de Graaf, 1998). Thus, aroma and taste together, i.e. flavor, had the main influences on consumers' oat bran product preferences. For the young, odor prevailed over taste, while the elderly paid an equal amount of attention to both odor and taste. Strong odor, with its impact on flavor, was assumed to mask sweetness changes for the young. As the olfactory function of the elderly might be diminished, they were able to react to sweetness changes more clearly. Thus, it is very important to consider elderly consumers' olfactory and taste functions when designing foods for them. Texture had relatively little impact on overall preference. However, it was slightly more important for the young than for the elderly.

Schutz and Wahl (1981) studied the relative importance of appearance, flavor, and texture on food acceptance using a questionnaire. The respondents were asked to divide ten points among appearance, flavor, and texture according to how important they thought these attributes were to food acceptance in an eating situation. In all, 94 foods were studied. Regardless of the food, the flavor was always rated as the most important attribute for food acceptance. Flavor predominated in liquid foods, such as beverages, while texture obtained the highest points in bland and mildly flavored foods, which had crisp or crunchy characteristics. Appearance was assessed as important in brightly colored fruits and vegetables, where appearance served as an indicator of quality.

Thus, the relative importance of texture, taste, and aroma is dependent on food product. In a study on apples, which are wet-crisp food, the texture and taste were found to be more important factors for consumer preference than aroma or appearance (Daillant-Spinnler et al., 1996). In another apple study, flavor prevailed over texture (Jaeger et al., 1998). Texture held the most important position when determining consumer preferences for muesli oat flakes and high-viscosity gel samples, even though the gel samples were not crisp or mild tasting. In the gel samples, texture may have overruled flavor as the flavor differences of the samples were relatively small compared with the texture differences. Thus, the consumer might have concentrated on differentiating between the samples by texture and given less attention to flavor.

Moskowitz and Krieger (1995) also studied the relative importance of flavor, texture, and appearance on six food categories. Again, regardless of food, flavor was the most important factor influencing overall preference, followed by texture and appearance. The study reported that the majority of people judge product acceptance by flavor, but some people do emphasize texture. The fact that people use different cues when evaluating food acceptance was also demonstrated by Damásio et al. (1999), who studied the effect of flavor and texture of low-sugar gels on consumer acceptance. The study showed that increasing flavor increased gel acceptance. However, subgroups that used mainly textural cues to judge acceptance of gels were found. Neither of these studies revealed what kind of people emphasized texture.

The studies discussed above are in agreement with the findings of Study IV. Aroma and taste, that together form flavor, contribute the majority of the overall pleasantness of the oat bran product. The study of Schutz and Wahl (1981) indicated that aging increased relative importance of flavor, while decreasing importance of texture. This was also the case in Study IV. The relatively minor importance of texture as compared with pleasantness of the oat bran product can also be explained by the flavor of the oat bran product not being bland and not belonging to the crisp product type. In addition, neither of the sample textures was difficult for the elderly to eat. The relative importance of texture remained small, with flavor overruling it. Thus, the importance of texture, taste and aroma are food-product-dependent.

5.5 Sensitivity tests

The ability of the sensitivity tests to predict fermented oat bran product evaluations of the elderly consumers seemed fairly inadequate in the case of Study IV. Further tests would be needed to investigate whether these sensitivity tests are capable for predicting sensory evaluations of actual samples or whether the tests are mainly useful when studying respondents overall sensory capacity. Suggested purposes for uses could be for example screening respondents for their eligibility for sensory panel members.

The effect of aging on texture perception was present in the case of the chewing efficiency. The young obtained better results in comparison with the elderly. Possible explanations for observed difference may be partly due to earlier experience. It is likely, that the young use more chewing gum compared to the elderly. In addition, dentures may have reduced chewing efficiency (Nagao, 1992; Ship, 1999). Unfortunately, dental status of the elderly was not studied and hereby the statement considering effect of dental condition remains unsolved. Muscle fatigue may also play a role in diminished chewing efficiency (Peleg, 1993), even though the 20 chews required in this particular test cause relatively little strain. The particle size discrimination test did not differentiate between the young and the elderly. Thus, the chewing efficiency test seems to offer effective test, which is also easy to carry out, for studying effects of aging in this particular field.

6 CONCLUSIONS

The work presented in this thesis revealed important information on segmentation of consumers' perceptions of texture and flavor of semisolid and solid food samples. The main results of Studies I-IV are presented in Table 7. Samples used in the studies were high-viscosity gel samples (strawberry flavored candies), muesli oat flakes, and yogurt-type fermented oat bran product. Effects of food components and processing parameters on food texture and flavor were also studied.

The results showed that each thickener and thickener combination used in the studies produced its own characteristic texture with specific flavor release properties. Other food components, such as sucrose and aroma, used in fermented oat bran products were also capable of producing texture, odor, and flavor differences. Furthermore, changes in processing conditions of muesli oat flakes were found to be essential for texture and flavor properties. Changes in food texture were noted to produce further changes in flavor properties. Thus, when the texture of food was changed, its flavor also underwent certain changes, and these changes were food- and component-dependent. These effects were present in all samples used in these studies.

Consumers' age affected food preferences. The studies showed that preferred flavor intensity was dependent on the type of food and the consumer's age. Elderly consumers tended to prefer amplified flavors, whereas their younger counterparts preferred milder ones. However, elderly consumers' preferences for amplified flavors existed only until a certain flavor concentration. After exceeding the optimum, the preference evaluations of the elderly decreased as was in the case with the young. The studies also showed that the elderly did not always prefer amplified food flavors. Mild flavors were preferred in some cases, and pronounced requirements were then placed on other food attributes, such as texture. Thus, when the food had a mild flavor, the sensory experiences were expected to be obtained from different sources. This was the case also with younger consumers, but the textural requirements set down by the elderly tended to be more precise, particularly if there was a chance that the texture may cause eating difficulties. Thus, texture that provided an easy eating experience was preferred. When ease of eating was guaranteed, elderly consumers were willing to accept textural modifications, perhaps even more so than younger consumers. The reason for the precise textural requirements of the elderly may derive from their diminished ability to chew as a consequence of missing teeth or wearing dentures, and because of rapidly occurring muscle fatigue.

The number of food types used in the studies was relatively limited. Because the factors affecting consumers' preference evaluations were food-dependent, further research is needed to obtain a more precise picture of this area. The studies focused on snack-type foods, e.g. candies, muesli oat flakes, and fermented oat bran product. Thus, it would be interesting to study wider range of food products and also take a look at liquid products.

The results indicated that relative importance of texture, taste, and aroma on consumer preferences was dependent on food type as well as consumer age. Flavor seemed to be a dominant factor, but whether the food had a mild flavor or crisp-type characteristics, texture increased its relative desirability. When the perceived differences in sample flavor were quite small, the importance of texture for sample differentiation increased. For muesli oat flake samples, the elderly consumers had more precise demands for pleasant texture than the younger age groups. Also, in the case of high-viscosity gel samples, the oldest age group was the most specific in their preference evaluations. Thus, where they preferred only one type of sample, the younger age groups found each sample to be almost equally acceptable.

For the fermented oat bran product, which was a semi-solid food product, the taste and aroma were by far the most dominant factors for the elderly. For the young, again, aroma had the largest relative importance. This was probably due its strong impact on the flavor of the sample materials. For both age groups, but particularly for the aged, texture was of lesser significance.

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