Influence of chewing and swallowing on flavour perception

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1. Abstract
Flavour perception plays a significant role in food acceptance and the ability of chewing and swallowing affects the perception of taste and flavour. This study investigates the influence of the numbers of chewing and swallowing on flavour perception.

Flavour and aftertaste of leek, onion and pepper were judged in texture-modified food by a trained sensory panel.

A significant effect of the numbers of chewing was found. For leek and onion flavours there were intensity maxima, while for pepper the perceived intensity increased with the numbers of chewing. The aftertaste declined in different ways for the different flavours. The numbers of swallowing did not affect flavour perception in any of the samples.

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2. Introduction
Flavour perception is playing a significant role in food acceptance, and thus it also influences nutrient intake (Donini, Savina and Cannella, 2003; Buettner and Schieberle, 2000). It is a very important factor to consider in the development of food products (Dattatreya, Kamath and Bhat, 2002).

When people are getting older a lot of physiological functions are changing. Among other things many elderly suffer from chewing and swallowing disorders (Pace, Stevens and Tucker, 2002) and they may lose their sensory capabilities (Roininen, Fillion, Kilcast and Lähteenmäki, 2003). One way to improve both the nutritional status and the general comfort of people with chewing and swallowing disorders is to modify the consistency of their food (Thornton, 2002). To design this type of food it is important to understand the overall process of flavour perception and the role of chewing and swallowing in this process.

Flavour is defined as the combined perception of taste, aroma and texture (Laing and Jinks, 1996). When a food is put into the mouth, many factors influence the perception of flavour. Tastes are perceived by chemical stimulation of receptor cells located in the tongue, the soft palate and the throat. There exist five common taste qualities: sweet, salty, sour, bitter and umami (Bender and Bender, 2000). Odorants are released from the food and transported retro nasally to the nasal cavity where they stimulate the olfactory receptor cells, and the sensory information is transformed into electrical signals and transported to the brain (Laing and Jinks, 1996). Chemesthesis/trigeminal nerves give additional information (Lovell, Jafek, Moran and Rowley, 1982) related to the senses of pain and temperature, like burning or cooling (Green, 1996).

Saliva plays an important role in the release of flavour compounds. Due to the ability of saliva to hydrate foods and dissolve flavour compounds, the amount of it influences flavour release.
Mastication increases the total surface of the food matrix which affects the diffusion of flavour compounds into the surrounding saliva (Harrison, 1998). This is supported by Taylor (1996) who found that volatile release was affected by hydration in the mouth.

Some recent investigations have shown the effect of swallowing on flavour perception; thus the effects on odour release from liquid food were studied by Hodgson, Linforth and Taylor, (2003) and Buettner and Schieberle (2000). Studies on solid food showed that mastication and swallowing influenced the time dependency of the flavour release (Taylor, 1996) and that longer mastication time resulted in increased flavour perception (Brown and Wilson, 1996; Buettner, Beer, Hannig, Settles and Schieberle, 2002).

Differences in flavour perception between individuals may be explained by differences in chewing efficiency (Brown, Dauchel and Wakeling, 1996), as well as in swallowing and salivation differences (Taylor, 2002).

On swallowing, most of the food is removed from the oral cavity (Harrison, Campbell and Hills, 1998), but breath-by-breath mass spectrometry has shown that some volatiles persist in the nose-space long after the food has been swallowed (Taylor, 1996). During the eating process the mouth and the nose are intermittently separated which prevents odour volatiles from reaching the nose. Immediately after swallowing, a so called swallow-breath transports odour molecules to the nose which allows for dynamic retro nasal flavour perception (Buettner, Beer, Hannig and Settles, 2001). Normand, Avison and Parker (2004) demonstrated that every following breath, up to one minute after swallowing, contains aroma volatiles.
The aim of this study was to examine how the number of chewing and swallowing affects the perception of flavours in texture-modified food while eating under defined conditions. Sensory descriptive analysis was used to describe perceived flavour intensities.

The study is part of a project entitled “Sensory Design and Optimisation of Consistency to Promote Health and Comfort in Elderly People”. The overall objective in this project is to develop innovative and healthy food products with sensory and consistency qualities that are in line with elderly consumers’ needs regarding healthy and sensory attractive products. In particular it considers how different food ingredients and food textures affect flavour perception in people with chewing and swallowing difficulties.

3. Material and Methods

3.1 Samples
Three different types of commercial texture-modified foods in the form of timbales were evaluated: mixed vegetables, carrot and spicy meat, respectively, Table 1. Deep frozen timbales were obtained from Findus Foodservices, Bjuv, Sweden.

<table>
<thead>
<tr>
<th>Product</th>
<th>Energy</th>
<th>Protein</th>
<th>Carbohydrate</th>
<th>Fat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carrot timbale</td>
<td>540kJ/130kcal</td>
<td>4g</td>
<td>9g</td>
<td>8.5g</td>
</tr>
<tr>
<td>Mixed vegetable timbale</td>
<td>580kJ/140kcal</td>
<td>4.5g</td>
<td>11g</td>
<td>8.5g</td>
</tr>
<tr>
<td>Spicy meat timbale</td>
<td>680kJ/160kcal</td>
<td>10g</td>
<td>9g</td>
<td>9.5g</td>
</tr>
</tbody>
</table>
3.2 Sensory evaluation

The timbales were analysed by descriptive profiling. The analyses were performed by an external trained panel (SIK, Sweden) consisting of twelve assessors (ten females and two males at the age of 30-68 years).

The evaluations were undertaken in a sensory laboratory equipped according to ISO 8586-1993. The judges were selected and trained according to ISO 8589-1988.

The sensory analyses were performed in three separate series with one type of product in each series and with eight judges in each series. Two training sessions per series were carried out. During the training sessions, 2h each, the judges developed a list of appearance, smell, taste and texture attributes for each type of foods. The resulting list contained the most distinct attributes of each product (table 2).

<table>
<thead>
<tr>
<th>Product</th>
<th>Flavour attribute</th>
</tr>
</thead>
<tbody>
<tr>
<td>vegetable timbale</td>
<td>leek flavour</td>
</tr>
<tr>
<td></td>
<td>leek aftertaste</td>
</tr>
<tr>
<td>carrot timbale</td>
<td>onion flavour</td>
</tr>
<tr>
<td></td>
<td>onion aftertaste</td>
</tr>
<tr>
<td>meat timbale</td>
<td>pepper flavour</td>
</tr>
<tr>
<td></td>
<td>pepper aftertaste</td>
</tr>
</tbody>
</table>

Further, the judges learned to judge the perceived intensities of these attributes in a controlled eating process, both directly after varying numbers of chewing and swallowing and as an aftertaste after twenty seconds. To define the eating process of each product, the assessors stated both the minimum needed and the maximum possible numbers of chewing and
swallowing. An eating scheme was thereafter developed for each product. The numbers of chewing and swallowing for each product is given in Figures 1-3.

**Fig.1.** Eating scheme for mixed vegetable timbale.

**Fig.2.** Eating scheme for carrot timbale.

**Fig.3.** Eating scheme for spicy meat timbale.
The judges were trained to utilise a 100 mm continuous line scale anchored with “low” at 10 mm and “high” at 90 mm from left end point. Markings on the line scale were converted into numbers ranging from 0 to 100 by the use of mouse and computer using FIZZ (2.00, Biosystèmes, France).

The samples were served in random order coded with three digit random numbers and evaluated in triplicate. Each judge evaluated nine samples in each series. All samples were evaluated in 2h sessions during 2 days. The judges took one tea-spoon full (5.5 g) of the sample in their mouth and were instructed to chew and swallow specific numbers of time before evaluating. The individual judges acted uniformly in the way of eating. To obtain the individual way of eating no guidelines were made for the frequencies of chewing or the count of swallowing. The samples (30 g pieces) were microwave-heated and served at a temperature of 50-60°C on paper plates. Water, neutral wafers, apples and cucumbers were used for cleaning the palate between the samples.

3.3 Statistical analyses
Analysis of variance (ANOVA) and Turkey’s post-hoc test were used to analyse the data of each flavour attribute. Differences in Turkey’s test were considered significant at \( p \leq 0.05 \) (SYSTAT 10.0, SPSS Inc.). 2-way ANOVA with assessors and products as fixed factors and 3-way ANOVA with numbers of chewing, numbers of swallowing and assessors as fixed factors were performed.
4. Results and Discussion
The timbales used in this study were easy-to-chew food. Their textures were modified to fit the needs of people with chewing and swallowing disorders.

Initially the judges were asked to indicate the possible minimum numbers necessarily needed and the maximum numbers possible of chewing and swallowing for each food. This was necessary because the timbales had different textures and specific eating strategies had to be specified for each type of food. Some judges found swallowing many times on demand to be difficult which might be explained by the fact that there exist differences in swallowing patterns between subjects (Buettner and Schieberle, 2000).

4.1 Main Effects
The numbers of chewing had significant effects on perceived flavour intensities when eating texture-modified food (Figures 4-6).

![mixed vegetable timbales](image)

<table>
<thead>
<tr>
<th>number of chewing(c) and swallowing(s)</th>
<th>1c 2s</th>
<th>8c 2s</th>
<th>16c 2s</th>
<th>1c 3s</th>
<th>8c 3s</th>
<th>16c 3s</th>
</tr>
</thead>
<tbody>
<tr>
<td>intensity</td>
<td>20</td>
<td>60</td>
<td>80</td>
<td>20</td>
<td>60</td>
<td>80</td>
</tr>
</tbody>
</table>

**Fig. 4.** Perceived intensities (panel means) in mixed vegetable timbales after different numbers of chewing and swallowing.
According to Harrison et al. (1998) the mastication process contributed to create new surfaces and therefore to flavour release. The influence of mouth movements on flavour perception was in accordance with earlier studies (van Ruth and Roozen, 2000; Burdach and Doty, 1987). Buettner et al. (2001) found that the length of the time that the food was kept in the oral cavity before being swallowed influenced the flavour that was perceived. The results in this study for leek and onion flavours indicated that there exists a maximum in perceived
intensity. After a certain number of chewing, the intensities of the perceived intensities declined (figures 4 and 5). This is in accordance with Buettner and Schieberle (2000) who found that the flavour profile changed after a long chewing time.

The aftertaste intensities declined in similar manners for all flavours. This finding was supported by Buettner et al. (2002) who found decreased flavour intensity by higher numbers of swallowing.

There were no significant differences between samples that were chewed the same number of times but swallowed different number of times (Figures 4-6). The results indicate that the number of chewing has a great controlling effect on the perceived flavour intensity, although the swallowing process is important to initiate the flavour perception. It has earlier been shown that swallowing was needed to get a flavour sensation and also to initiate the perception process (Hodgson et al., 2003) after the opening of the velum-border (Buettner et al., 2003). In the present study onion flavour was perceived in carrot timbales that were swallowed without any chewing at all (Figure 5).

Time Intensity studies have previously shown that trained sensory judges differ in their perception of sensory attributes (Wendin, 2001; Dijksterhuis, 1995). This was also observed in this study where the effect of the factor judge was statistically significant on perceived intensities of both flavours and aftertastes. The differences can probably be explained by differences in the physiology of the judges, i.e. differences in chewing and swallowing patterns (Togashi, Morita and Nakazawa, 2000; Buettner and Schieberle, 2000), saliva secretion (Sreebny, 2000), dental status (Winkler, Garg, Mekayarajjananonth, Bakaeen and
Khan, 1999) and chewing efficiencies (Brown et al., 1996). Some of the judges found swallowing a specified number of times being difficult.

4.2 Interaction Effects
The systems used in this study were considerably complex and the statistical evaluations showed that there were significant interactions both between judges and numbers of chewing and between judges and numbers of swallowing.

The interaction between judges and numbers of chewing was significant for all of the studied flavours and their aftertastes. It was interesting to observe that if one judge differed from the rest of the panel in the perception of a particular flavour the same judge also differed in the same manner in the perception of the aftertaste of the same flavour. However, it was not the same judge who consequently differed from the others for all the flavours and their aftertastes.

Differences between the assessors might be explained by both physiological and psychological factors (Dijksterhuis, 1995).

Significant interactions also occurred between judges and numbers of swallowing in the perception of pepper and leek and their aftertastes.

There was no significant interaction between numbers of chewing and numbers of swallowing.

4.3 Concluding Discussion
The results indicate that flavour quality plays a significant role in flavour perception. Differences were found between on one side the perception of leek and onion flavour and on the other side the perception of pepper. This might be explained by the different types of stimulation involved. Leek and onion flavours are mainly perceived by the sense of olfaction while pepper perception also has a trigeminal part (Green, 1996). Buettner et al. (2002) found
that the adhesive force of food matrices affects perceived intensity. This was in line with Lawless and Heymann (1998) who found different persistence effects over time in different flavour qualities. In our study leek and onion flavour perception had an intensity maximum in the middle number of chews (6 and 8 respectively), then the intensity decreased. The perceived pepper intensity did not decrease with increasing chewing numbers. This was in accordance with Lawless (1984) who found longer decay times in pepper stimulation. The observed interaction effects showed that the systems were complex and that more research is needed.

5. Conclusions
Perceived intensities of flavours in different kinds of timbales, rated by a trained sensory panel, were found to be significantly affected by the numbers of chewing but not by the numbers of swallowing.

It was found that leek and onion flavours reached maximum intensities after certain numbers of chewing and then declined when the numbers of chewing increased further. Aftertastes were also affected by the numbers of chewing, but showed lower effects. The perceived intensity of pepper increased continuously with the numbers of chewing.

The numbers of swallowing did not significantly affect the intensities of leek, onion and pepper flavours.
6. References
Cambridge: Woodhead Publishing Ltd.


