## Effects of NaCl substitution on the sensory properties of sausages: temporal aspects

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**Abstract**

The aim of this study was to determine the effects of different salt substitutes on the overall sensory perception of sausages. TDS was used to explore the temporal perception of the samples and DA was used as a reference method. Grill-style sausages with different levels of salt reduction combined with different salt substitutes (KCl, Na-lactate, K-lactate/Na-diacetate and milk minerals) were used as experimental samples. Results showed that TDS elucidated sensory information that was not emphasized by DA and vice versa. TDS revealed differences in the temporal perception of the aftertaste between KCl substituted samples, while no such differences were observed from DA. Overall, TDS provided complementary information to DA regarding the sensory effects of sodium reduction and substitution.

Keywords: Sensory, Temporal Dominance of Sensations, Descriptive Analysis, Sausage, Salt reduction

# 1. Introduction

In many industrialized countries the sodium intake exceeds the nutritional recommendations. A high sodium intake has been linked to health problems, such as hypertension and consequently to an increased risk of cardiovascular diseases (WHO, 2007). NaCl is the main source of sodium in today’s human diet, and in European countries more than 70 % of the dietary salt intake is estimated to come from processed foods. Especially processed meat products contain relatively high amounts of sodium (Doyle & Glass, 2010; James, Ralph, & Sanchez-Castillo, 1987; Mattes & Donnelly, 1991; Norwegian Directorate of Health, 2010). As sausages are consumed relatively frequent in Norway, a sodium-reduction in such products may represent an important contribution to a general reduction of sodium intake in the population.

Sodium chloride is one of the oldest and most familiar food ingredients (McGough, Sato, Rankin, & Sindelar, 2012). There is no single ingredient that fully can substitute the effect of sodium chloride in foods. Historically, salt has been used for preservation, by lowering water activity to prevent microbial growth. Furthermore, sodium increases the palatability of foods, by contributing to saltiness, enhancing the overall flavor and sometimes suppressing bitterness (Dötsch et al., 2009). Salt is also responsible for the desired textural properties of processed meats as it increases the water holding capacity and the binding properties of proteins. It also increases the viscosity of meat batter and facilitates the incorporation of fat to form heat-stable meat batters (Desmond, 2006; Garcia-Garcia & Totosaus, 2008; Terrell, 1983). Moreover, sodium chloride is a cheap ingredient and the use of any substitute is likely to increase production costs. In addition, a reduction might have economic consequences for the producer due to reduced production yield.

In order to prevent reduction in product quality and profitability for the food industry, a reduction of sodium should be combined with compensatory measures such as the use of salt substitutes and enhancers. Common strategies are replacing parts of the NaCl with chloride salts (e.g. KCl, CaCl2 and MgCl2) or non-chloride salts (e.g. phosphates and lactate salts) either separately or in combination (Ruusunen & Puolanne, 2005).

Among the chloride salts, potassium chloride (KCl) is the most commonly used alternative (Dötsch et al., 2009). KCl contributes to some saltiness by itself, but sometimes imparts off-flavors such as bitterness and metallic flavor (Doyle & Glass, 2010). Previous research has shown that it is possible to replace up to 30 - 40 % of NaCl with KCl in fermented sausages. At higher levels of KCl substitution, a reduction in saltiness and a significant increase of bitterness and hardness has been observed (Gelabert, Gou, Guerrero, & Arnau, 2003; Gou, Guerrero, Gelabert, & Arnau, 1996). Non-chloride salts, such as salts of organic acids, e.g. Na-lactate, K-lactate and Na-diacetate, are other examples of ingredients used for compensating loss of antimicrobial effect and loss of flavor in NaCl-reduced meat products (Doyle & Glass, 2010). The antimicrobial effect of lactates can be enhanced synergistically in combination with other organic salts (Devlieghere, Vermeiren, Bontenbal, Lamers, & Debevere, 2009).

Milk minerals, or dairy concentrates, is a relatively new type of salt substitute on the market, and is proposed as a salt enhancer applicable for moderate sodium reduction in many different foods (Pszczola, 2007; US Institute of Medicine, 2010). Dairy concentrates are usually fractionated from whey through different isolation techniques. In addition to lactose and calcium, such products naturally contain salts of sodium, potassium, magnesium and calcium phosphate (Walstra, Wouters, & Geurts, 2005). However, the concentration of constituents and the chemical composition of such milk mineral concentrates may vary according to the fractionation process. Though the mechanisms are not fully understood, the observed salt enhancing properties of milk minerals may be attributed to the mineral salts and the flavor enhancing properties may be attributed to the non-protein nitrogen compounds (Minasian, 2011).

There is a growing focus on a healthier diet among consumers in today society (Desmond, 2006). The development of more palatable sodium-reduced products is important in order to guide consumers towards more healthy food choices. In this context, it is essential to characterize and understand the sensory effects of sodium reduction in foods. Sensory analysis is the most appropriate approach to describe the nature and to quantify the intensity of the sensory properties of food. Descriptive Analysis (DA) is the standard methodology for describing the sensory profiles of products. During eating and drinking, upon the influence of mastication and salivation, the sensory properties of foods change (Ng et al., 2012). To take into account the dynamics of perception and the multidimensionality of the perceptual space, the use of a new method called Temporal Dominance of Sensations (TDS) is gaining attention (Pineau et al*.*, 2009). TDS is a descriptive method that enables several attributes to be evaluated simultaneously during consumption of a product. In practice, TDS consists of presenting a panel with a complete list of attributes on a computer screen and asking them to identify, and sometimes to also score the intensity of sensations perceived as “dominant” during consumption of a product. As an outcome, TDS provides a sequence of dominant sensations during a certain time period (e.g. mastication, aftertaste). While two products may have the same average intensities for certain sensory attributes, the sequence in which these attributes are perceived may be different. In addition, with this methodology it is possible to study the interaction between attributes, by recording the evolution of the dominant attributes (Le Reverend, Hidrio, Fernandes, & Aubry, 2008). Upon our knowledge, TDS have not been applied previously to characterize the sensory properties of sodium reduced foods.

**The aim of this study** was to determine the effects of different salt substitutes on overall sensory perception of sausages. TDS was used to explore the temporal perception of the samples and DA was used as a sensory reference method. It was of specific interest to learn if the combined information from TDS and DA would provide a more comprehensive overview of the sensory effects of sodium reduction and substitution. Such information may useful for optimization of recipes.

# 2. Materials and Methods

## 2.1 Samples

Eight sodium reduced sausages and one full sodium sausage (control) were produced by the food manufacturer Stabburet AS at their pilot plant at Råbekken, Norway (Table 1). The control was a grill-style sausage popular in the Norwegian market. The basic recipes contained the following ingredients: meat/fat mix with 25 % fat content (43 %), nitrate salt (0.8 %) phosphate (0.3 %), sodium caseinate (1.3 %), pork back fat (10.0 %), starch (5.7 %), glucose (0.3 %), sodium ascorbate (0.04 %), spice mix (0.7 %). The treatments were a combination of different levels of sodium reduction and different sodium substitutes. Choice of sodium substitutes and levels and range of sodium reduction were determined by the manufacturer based on previous experiences from relevant experiments. Four different reduction levels were used; reduction to 0.7 % (samples 1), reduction to 0.6 % (sample 2), reduction to 0.5 % (samples 3, 4, 6, 7, 8) and reduction to 0.2 % (sample 5). Five different sodium substitute strategies were used; KCl (samples 1, 2 and 3), milk minerals (samples 4 and 5), combination of sodium lactate and sodium diacetate (sample 6), combination of K-lactate and Na-Diacetate (sample 7) and potassium lactate (sample 8). Water was added according to the recipe of the individual samples (35.86 – 37.00 %).

The sausages were manufactured using a bowl chopper (Kilia 20 liter, Kilia Germany). The meat-fat mixture was mixed with the NaCl (amount depending on sample), nitrite salt, phosphate, ice-water and KCl or milk minerals (depending on the sample), until a temperature of 0 °C was reached. Next, sodium caseinate, ice-water, spices, pork back fat, starch and lactate salts/sodium diacetate (depending on sample), was added to the bowl chopper, and mixed until temperature reached 14 °C. The emulsion was transferred to a vacuum filling machine (Handtmann VF50, Handtmann Germanyfiller) and stuffed into 28 mm cellulose peels (Viscofan 28 mm 55 ft, Viscofan). Sausages were hung on smokehouse sticks, placed on a smokehouse truck and stored overnight at 0-4°C prior to the cooking and smoking process. Cooking was done in a single truck thermal processing oven (Deutsch cook and smoke cabin, Deutsch Germany) for 90 min in 150 ᵒC until a core temperature at 65ᵒC. Finally, the sausages were placed in PA/PE 90 vacuum pouches (Sacs sous vide, Bokken) and vacuum packaged (Hencovac 1500H, Hencovac, The Netherlands). After cooking and cooling all samples were vacuum-packed separately. Samples were transported to the test location at Nofima (Ås, Norway) for storage at 4 °C.

**Table 1**

Overview of salt content and salt substitution in samples

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|   |   |   |   | Salt substitutes (%) | Sensory analysis |
| Sample | NaCl (%) | Nitrate salt (%) | Total salt (%) | KCl | Milk minerals | Na-Lactate/ Na-Diacetate | K-Lactate/ Na-Diacetate | K-Lactate | DA | TDS |
| Control | 0.9 | 0.8 | 1.7 | - | - | - | - | - | x | x |
| 1 | 0.7 | 0.8 | 1.5 | 0.256 | - | - | - | - | x | x |
| 2 | 0.6 | 0.8 | 1.4 | 0.256 | - | - | - | - | x |   |
| 3 | 0.5 | 0.8 | 1.3 | 0.384 | - | - | - | - | x | x |
| 4 | 0.5 | 0.8 | 1.3 | - | 0.4 | - | - | - | x | x |
| 5 | 0.2 | 0.8 | 1.0 | - | 0.7 | - | - | - | x |   |
| 6 | 0.5 | 0.8 | 1.3 | - | - | 1.5 | - | - | x |   |
| 7 | 0.5 | 0.8 | 1.3 | - | - | - | 1.5 | - | x | x |
| 8 | 0.5 | 0.8 | 1.3 | - | - | - | - | 1.5 | x |   |

% indicates weight % of total recipe. X indicates if samples were included in analysis.

The samples were heated until a core temperature of 65°C in an Electrolux Air-o-steam-oven (Combi LW 6 GN 1/1 Gas) at 150 °C and 0 % steam. Although the sausages are called “grill-style” this procedure was similar to how such a product normally is heat-treated in commercial settings. After cooking, the samples were cut into pieces of 1.5 ± 0.1 cm length. Average weight of the samples was 7.9 ± 0.6 g. For TDS analysis assessors were served one piece of the sample, while for DA assessors were served two adjacent pieces. Samples were served in a white porcelain bowl labeled with a three-digit code and preheated in a hot closet at 60 ± 1 °C. A lid was placed over the sausage sample to prevent heat loss during the evaluation. Assessors had electrical heating plates (60 ± 1 °C) available in the sensory booths. Serving temperature of the samples was 52 ± 2 °C.

## 2.2 Sensory Analysis

Sensory evaluation was conducted on three consecutive days, starting 11 days after the production of the sausages. The sensory analysis was conducted by a trained sensory panel at Nofima. All assessors were selected and trained in accordance with ISO 8586-1 (ISO, 1993) in a sensory laboratory designed in accordance with ISO 8589 (ISO, 2007). Each assessor evaluated all samples using EyeQuestion for direct recording of data (v3.8.7, Logic8, Holland). All samples were expectorated and unsalted crackers and lukewarm water was available for rinsing.

### 2.2.1. TDS

Trained sensory panelists (n=12) were used for TDS. Panelists were introduced to the notion of temporality of sensations and dominance using the analogy of an orchestra playing music, as proposed by Ng et al*.* (2012). The dominant sensation was defined as the sensation catching one’s attention and it was specified that the dominant sensation is not necessarily the attribute with the highest intensity (Pineau et al., 2009).

For generating a list of dominant attributes, the panelists were instructed to write down all attributes they perceived as dominant during a brainstorm session performed with the control sample, sample 3 and sample 7 (Table 1). These three samples were expected to represent the relevant attributes for all samples. Panelists found both flavor and texture attributes to be dominant and the most frequently quoted attributes were selected for training. During three following training sessions, attributes and evaluation parameters, such as time for expectoration and maximum time of assessment, were alternated and adjusted through discussions with the panel. The final list of attributes comprised of four flavor and three texture attributes (Table 2). In a pre-test, assessors were served two samples (control sample and sample 7) and the sequence of dominant sensations for these samples discussed with the panel.

The final TDS evaluation was performed for five different samples: the control sample and samples 1, 3, 4, and 7. Formulation 1 and 3 were included as they represented the lowest and highest level of sodium reduction for the KCl substituted samples. Sample 4 was included as it had milk minerals substitution at the same level of sodium reduction as sample 3, and sample 7 included as potassium lactate/sodium diacetate was considered as the most relevant among the lactate salt substitutes, based on the experience of the producer.

The TDS main evaluation was performed during one day in four separate sessions with minimum 15 min breaks between sessions. The total number of servings were 16, consisting of 5 sausage samples in triplicate plus one warm up sample included in the first session. The serving order was randomized across all sessions. Due to practical issues related to heating, all assessors were served the same sausage sample simultaneously. The attribute list for TDS was presented on the computer screen with the same order for all panelists. Panelists were instructed to put the sample into their mouth and click the “start” button on the screen to begin the collecting of the data (time = 0). During the analysis the panelists selected the dominating sensation by clicking the box with the corresponding attribute. A chosen attribute was registered as dominant until another attribute was chosen. Panelists were free to choose the same attribute multiple times or not at all.

The assessors were instructed to start assessment with biting on the skin side of the sausage sample. During mastication, panelists were free to chew as they wanted. After 25 seconds, the message “spit out” appeared on the screen. After expectoration, panelists were instructed to continue their evaluation of the aftertaste until no sensation was perceived as dominant, at which point they were instructed to press the “stop” button, or until data acquisition had stopped automatically after 45 seconds.

**Table 2**

Sensory attributes used for Temporal Dominance of Sensations (TDS). F=flavor, T=texture.

|  |  |
| --- | --- |
| **Attribute** | **Definition** |
| Salt-F | Basic taste associated with sodiumchloride (NaCl). |
| Spice-F | Flavor of spices (pepper, paprika, garlic, nutmeg). |
| Meat-F | Flavor of pork meat. |
| Smoke-F | Flavor of smoke. |
| Soft-T | Mechanical textural attribute related to the force required to bite through the product. Low level of hardness.   |
| Juicy-T | Surface textural attribute related to the perception of a high level of water absorbed by or released from the product. |
| Pasty-T | Mechanical textural attribute related to the cohesiveness of a tender product and the effort required to desintegrate the product.  |

### 2.2.2. Descriptive Analysis

DA was conducted by the same trained sensory panel (n=10) on the day after the TDS evaluation according to Generic Descriptive Analysis as described by Lawless and Heymann (2010). A list of 19 attributes (odor, flavor and texture attributes) was generated from a brainstorming session (Table 3). Attributes were evaluated using a continuous, non-structured scale ranging from no intensity (1) on the left to high intensity (9) on the right. Panelists were calibrated on all attributes in a pre-test. DA was performed in one day over five sessions (maximum 4 servings per session) with minimum 15 min breaks between sessions. Nineteen servings consisting of 9 sausage samples in replicate plus one warm-up sample were assessed. The serving order was randomized across all sessions. Due to practical issues related to heating, all assessors were served the same sausage sample simultaneously. The assessors were instructed to start assessment with biting on the skin side of the sausage sample. During mastication, panelists were free to chew as they wanted.

**Table 3**

Sensory attributes for Descriptive Analysis (DA). O=Odor, F=flavor, T=texture.

|  |  |
| --- | --- |
| **Attribute** | **Definition** |
| Sour-O | Related to a fresh, sour/sweet odor |
| Meat-O | Odor of pork meat |
| Spices-O | Odor of spices (pepper, paprika, garlic, nutmeg) |
| Smoked-O | Odor of smoke |
| Sour-F | Related to a fresh, sour/sweet taste |
| Salt-F | Basic taste associated with salt, sodiumchloride (NaCl) |
| Bitter-F | Basic taste associated with bitter (caffeine) |
| Umami-F | Basic taste associated with umami, monosodiumglutamate (MSG) |
| Meat-F | Taste of pork meat |
| Spices-F | Taste of spices (paprika, garlic, nutmeg)  |
| Pepper-F | Taste of pepper spice |
| Flour-F | Taste of wheat flour |
| Metallic-F | Taste associated with metal, Ferrous sulfate (FeSO4), iron (Fe) |
| Smoked-F | Taste of smoke |
| Hardness-T | Mechanical textural attribute related to the force required to bite through the product. |
| Juicy-T | Surface textural attribute related to the perception of a high level of water absorbed by or released from the product |
| Fattiness-T | Surface textural attribute relating to the perception of the amount of fat in a product. Perception of an oily coating from the sample in the mouth. |
| Cohesiveness-T | Mechanical textural attribute related to the degree to which a product can be deformed before it breaks. |
| After taste | Perception of taste 30 s after expectoration of the product. |

## 2.3 Statistical Analysis

### 2.3.1 TDS

Dominance rates of the attributes over time, i.e. the proportion of selection of an attribute as dominant, were calculated for each sample (Pineau, et al., 2009). These dominance rates were calculated by dividing the number of evaluations of an attribute as dominant over all replications by the total number of evaluations (i.e. panelists x replications). The higher the dominance rate, the better the agreement is among panelists. To facilitate interpretation of the TDS curves, two limits, i.e. chance level (*P0*) and significance level (*Ps*), are displayed on each TDS plot. The chance level represents the dominance rate that an attribute can obtain by chance. *P0* is calculated by dividing 1 by the number of choices given to a panelists at each time point, i.e. *p+1*, *p* being the number of attributes, and *+1* referring to “no sensation condition”, since not all panelists may start to experience sensations at the very beginning of the evaluation, or stop to experience sensations at the same time (Lenfant, Loret, Pineau, Hartmann, & Martin, 2009). The significance level of dominance of an attribute for each time point represents the smallest value of the proportion being significantly higher than the chance level *( = 0.05*). *Ps* is calculated using a binomial distribution (Labbe, Schlich, Pineau, Gilbert, & Martin, 2009).

### 2.3.2 QDA

PanelCheck 1.3.2 (www.panelcheck.com) was used to evaluate the panel performance. For determination of attributes discriminating between samples a two-way analysis of variance (ANOVA) with product as a fixed factor, panelist as a random factor and product x panelist as an interaction factor was performed. Tukey’s Multiple Comparisons Test was applied to determine which products were significantly different. The significance level was defined to =0.05. Statistix v 9.0 (Analytical Software, USA) was used for the analysis.

### 2.3.3 Multivariate data analysis

Tucker-1-plots were used to evaluate the consensus of sensory attributes among the panelists. Tucker-1 is a method which is applied for considering common information in a number of data-blocks. The method provides useful scatterplot for interpretation. Instead of analyzing the different data blocks separately, one concatenates the blocks and uses a standard PCA on the whole concatenated block.

Moreover, multivariate analysis was performed using Principal Component Analysis (PCA) and Unscrambler X 10.1 (CAMO software AS, Norway) to study the main sources of systematic variation in the average sensory descriptive data for DA (significant attributes, p < 0,05) (mean centered data, no standardization). The models were cross-validated and the results were interpreted with explained variance values and correlation loadings plots with circles indicating 50% and 100% explained variance, respectively (Westad, Hersleth, Lea, & Martens, 2003). Samples were projected into the correlation loadings plots as passive object indicator-variables (Martens & Martens, 2001).

# 3. Results

## 3.1 TDS

TDS plots with significant dominant attributes for control sample and samples 1, 3, 4 and 7 are presented in Fig. 1.

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| --- | --- |
|  |  |
|  |  |
|  |  |

**Fig. 1:** TDS curves

Horizontal lines indicate frequency (%) for significance limit (upper line) and chance limit (lower line). Vertical line indicates division between mastication (1-25s) and aftertaste period (26-45s). Attribute descriptors in plot only indicate first incident of significant dominance during the respective period. Only significant information is shown.

Fig. 1 shows that all samples have dominance of softness, saltiness and spice flavor during the mastication period and saltiness and spice flavor during the aftertaste period. Softness is the first dominant sensation for all samples and appeared between 3 and 7 seconds.

The control sample (0.9 % NaCl) has dominance of salty taste from 5 seconds until expectoration at 25 seconds. In addition, the mastication period is mainly dominated by spice flavor, in addition to a brief dominance of smoke flavor. Texture attributes such as juiciness and pastiness also dominate. For the aftertaste period saltiness dominates over spice flavor until 38 seconds after which spice flavor dominates slightly.

During mastication sample 1 (0.7 % NaCl - 0.256 % KCl substitution) has dominance of salty taste from 7 seconds throughout mastication period except at 18 seconds, with simultaneous dominance of spice flavor and a brief dominance of meat flavor. Saltiness dominates over spice flavor during the whole aftertaste period.

Sample 3 (0.5 % NaCl - 0.384 % KCl) has dominance of salty taste from 7 seconds throughout the mastication period, with simultaneous dominance of spice flavor and brief dominance of meat flavor. For the aftertaste period saltiness dominates over spice flavor until 33 seconds after which spice flavor dominates.

Sample 4 (0.5 % NaCl – 0.4 % milk minerals substitution) has dominance of salty taste from 6 seconds and throughout the mastication period except between 19 and 21 seconds with simultaneous dominance of meat, smoke and spice flavor. For the aftertaste period saltiness and spice flavor dominates equally until 40 seconds after which spice flavor dominates.

Sample 7 (0.5 % NaCl - 1.5 % K-lactate/Na-diacetate substitution) has dominance of saltiness from 5 seconds throughout the mastication period except between 9 and 10 seconds with simultaneous dominance of spice flavor and pastiness. Saltiness dominates over spice flavor during the whole aftertaste period.

## 3.2 Descriptive Analysis

Mean intensity scores of significant sensory descriptors obtained from DA are shown in Table 4. Only flavor and texture attributes are presented as no significant differences were found for odor attributes. Fig. 2 show the correlation loadings plot from PCA for the mean intensity of the sensory attributes significantly discriminating between samples from DA.

**Table 4**

Mean intensity scores (panelists & replicates) for significant attributes from DA. F=flavor, T=texture.

|  |  |
| --- | --- |
|   | Treatments |
| Attributes | **control** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** |
| **meat-F\*** | 3,7c  | 3,8bc  | 4,4a  | 3,9abc  | 4,2abc  | 4,1abc  | 4,4ab  | 4,4ab  | 3,9abc  |
| **flour-F\*\*** | 3,0a  | 3,4a  | 2,0b  | 2,9ab  | 2,5ab  | 2,5ab  | 2,5ab  | 3,0a  | 2,7ab  |
| **hardness-T\*\*\*** | 3,4bc  | 3,3bc  | 3,6bc  | 3,2c  | 3,6bc  | 3,5bc  | 4,2a  | 3,8ab  | 3,6bc  |
| **juicy-T\*\*\*** | 5,4ab  | 5,5ab  | 5,2abc  | 5,7a  | 5,2abc  | 5,4ab  | 4,7c  | 4,9bc  | 5,4ab  |
| **fattiness-T\*\*\*** | 5,0a  | 5,0a  | 4,9ab  | 5,0a  | 4,6ab  | 4,7ab  | 4,8ab  | 4,4b  | 4,9ab  |
| **cohesiveness-T\*** | 3,9ab  | 3,5ab  | 4,1a  | 3,8ab  | 4,2a  | 3,9ab  | 4,0ab  | 3,0b  | 3,5ab  |

Different letters within a column indicate significant difference in mean intensity scores,

\* = p<0.05, \*\* = p< 0.01, \*\*\* = p<0.0001

Table 4 shows that significant differences were found (p < 0.05) between samples for two flavor attributes, i.e. meat flavor and flour flavor, and four texture attributes, i.e. hardness, juiciness, fattiness and cohesiveness. Sample 2 (0.6 % NaCl - 0.256 % KCl substitution) sample 6 (1.5 % Na-lactate/Na-diacetate substitution) and sample 7 (1.5 % K-lactate/Na-diacetate substitution) have significantly higher meat taste than control sample. In addition, sample 2 has significantly lower flour taste than the control sample. Sample 6 has significantly higher hardness and lower juiciness compared to the control sample. Sample 7 has significantly lower fattiness compared to the control sample. There were no significant differences between samples 1, 3, 4, 5, 8 and the control sample.

|  |  |
| --- | --- |
|  |  |



**Fig. 2:** PCA correlation loadings plot for the average intensity of the attributes (mean centered data, non-standardized) significantly discriminating between samples, based on 2-way ANOVA (α = 0.05). Samples are projected into the correlation loadings plots as passive object indicator-variables. The inner and outer circle indicates 50% and 100% explained variance, respectively. F = flavor, T = texture.

Fig. 2 shows that the first two components explained 86% of the variance in the sensory attributes: PC1 accounted for 53% of the systematic variation in the data and PC2 for 33%. PC1 is mainly explained by flour flavor, juiciness and fattiness to the right side of the plot and meat flavor and hardness to the left side of the plot. PC2 is explained with cohesiveness. Samples 1 and 3 (KCl substitutions) and samples 4 and 5 (milk minerals substitutions) are separated along PC1. Among the samples with the lactate salt substitution, sample 6 (Na-lactate/Na-diacatetate) is separated from sample 8 (K-lactate) along PC1, whereas sample 7 (K-lactate/Na-diacetate) is separated from sample 8 along PC2. Samples positioned closest to the control sample are sample 3, sample 1 and sample 8.

# 4. Discussion

## 4.1 TDS

TDS revealed differences in the number and types of dominant sensations between the control sample and the sodium-substituted samples for the mastication period. Softness, saltiness and spice flavor were found to dominate in all samples, while meat flavor, smoke flavor, juiciness and pastiness only dominated for some of the samples. The control sample had a total of six dominant sensations during the mastication period compared to five for sample 4 (milk minerals) and four for sample 1, 3 and 7. Fig. 1 also shows the samples 1, 3 and 4 had higher dominance rates for saltiness compared to the control sample during the mastication period. The difference in the number of dominant sensations and dominance rates could be related to textural differences. The control sample was the only sample with dominance of juiciness which could indicate that the samples with salt substitutes were less juicy. In addition, the control sample and sample 7 had dominance of pastiness during the mastication period. This may indicate that sausages with a more juicy and pasty texture gives a more balanced overall perception. In TDS, all attributes compete simultaneously for the attention of the assessors, and a few dominant attributes may easily dominate the perception if they are not balanced by other attributes.

For the aftertaste period, the main difference compared to the control sample was found for samples with KCl substitution (sample 1 and 3). Fig. 1 showed that sample 1 had a higher dominance of salty taste at the end of the aftertaste period while sample 3 had a higher dominance of spice flavor for the same period. Accordingly, this result showed that different levels of KCl substitution may affect the temporal perception during the aftertaste period. Even though spice flavor may not be a typical off-taste, the increased dominance of this flavor during the aftertaste may affect overall perception and acceptance of such products.

Overall, these results demonstrate that the investigated salt substitutes affected the dynamic perception of the samples. Results showed that the main temporal differences between the investigated samples were found in the aftertaste period. Results also showed that there were differences between samples related to the dominance of saltiness and texture attributes during the mastication period.

## 4.2 DA

DA revealed relatively few significant differences in sensory descriptors between the sodium-reduced samples and the control sample. The DA revealed no differences for odor attributes, saltiness or off-tastes typically related to sodium substitutes i.e. bitterness and metallic flavor. Significant differences were observed between the control sample and samples 2, 6 and 7 for meat flavor, flour flavor, hardness, juiciness and fattiness. A significant difference in meat and flour flavor between sample 2 and the control sample without corresponding differences in sample 1 and 3 was unexpected as all three samples had KCl substitution. Sample 2 had the same level of KCl substitution as sample 1 but with less added NaCl (0.6 %). The PCA of DA results (Fig. 2) showed that the samples with KCl substitution (samples 1 and 3) were most similar to the control sample, described by high intensity of fattiness, juicy and flour flavor, while sample 2 was located on the opposite side of the plot, described by high intensity of meat flavor. This result indicates either an interaction between sodium chloride and KCl within the respective concentration range, or it could be a result of uncontrolled variation in the production process. A registration of drip loss after cooking of the sausages, showed a lower value for sample 2. According to the manufacturer this could be related to the positioning of the sample in the cooking cabinet.

The samples with Na- or K-lactate/Na-diacetate substitution (samples 6 and 7) had significant increase in meat flavor compared to the control sample. In addition, these samples had significant differences in textural attributes compared to the control sample. Sample 6 was significantly harder and less juicy while sample 7 had significantly lower fattiness than the control sample. Textural changes have been observed for salt substitution with lactate salts in previous studies on fermented sausages (Gelabert et al., 2003; Gou et al., 1996; Guardia, Guerrero, Gelabert, Gou, & Arnau, 2008). Devlieghere et al. (2009) reported that lactates combined with Na-diacetate synergistically enhanced the antimicrobial effect but sensory effects were not investigated in this study. According to the literature, K-lactate and Na-lactate also have different intrinsic tastes. Na-lactate is described as having an acidic taste while K-lactate is described as having a bitter taste (Pearson & Gillett, 1996).

Overall, the sensory differences between samples described by DA were relatively small. This corresponds to results from previous studies on salt reduction and salt substitution at similar levels.

## 4.3 Implications

This study shows that TDS may add extra information about temporal sensory nuances when working with sodium reduction and substitution in specific industrial products. Even though the demonstrated effects were not large in this study, the use of TDS highlighted information that was not emphasized by DA and vice versa. Results from the current study also showed that information regarding significant differences for specific attributes revealed by DA not necessarily is reflected as dominant in TDS. Similarly, Ng et al. (2012) found that mean intensities in DA could not predict the dominance of sensations in TDS.

Results from DA indicate that sodium reduction is feasible for such products up to the investigated levels i.e. 23 % for KCl substitutes and lactate salts. This adds to results from previous research by Gou et al. (1996) and Gelabert et al. (2003) which have shown that KCl and K-lactate can replace up to 30-40% of NaCl in meat products with only smaller sensory changes. Almli & Hersleth (2012) found similar results for smoked salmon, where no significant differences in DA were observed for 1/3 replacement of NaCl by KCl.

DA results from the current study also showed that sodium reduction up to 40 % combined with milk minerals substitution (sample 5) is possible without observing significant differences in the descriptive profile. The results from TDS showed that sample 4 (milk minerals substitution, 23% NaCl reduction) had a relatively similar temporal profile to the control sample except for differences in dominance of textural attributes. This indicates that milk minerals have a promising potential as a salt and flavor enhancer. However, it’s important to stress that this experiment included only one example of a milk mineral based salt replacer. Accordingly, this type of salt substitute needs to be followed up with other applications.

The intention behind conducting the DA after the TDS evaluation was to reduce the influence of the typical analytical mindset used for DA during the TDS evaluation. While TDS also requires analytical thinking, assessment must be performed much faster and intuitively. Performing TDS before DA also means that TDS was performed without prior knowledge about actual sensory differences between the samples. Thus, sample selection was determined only based on previous experiences with similar products. Due to practical reasons, TDS evaluation was performed only on a subgroup of the sodium reduced formulations. It would have been interesting to also include sample 2 in TDS to compare the temporal profiles of the KCl substituted samples. Accordingly, based on the experiences from this study, we would claim that it’s an advantage to have background information from DA before performing the TDS or TDS.

# 5. Conclusions

In conclusion, the combined use of TDS and DA provided a broader sensory description of the effect of sodium reduction and substitution. Even though a relatively small number of discriminating attributes was revealed by DA, TDS indicated differences in the dynamic perception of the sodium reduced sausages compared to the control sample, specifically during the aftertaste. Further studies should include more detailed investigations on the effects of salt reduction and/or salt-substitution on the dynamic perception of products and its relevance for consumer acceptance.

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