Salt reduction without consumer awareness using a sensory threshold approach: a case study in meat products

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1. Introduction

High dietary sodium intake has been associated with non-communicable diseases (NCD), including hypertension, coronary heart disease and strokes (WHO, 2015). The World Health Organization’s 2030 Agenda for Sustainable Development recognizes NCDs as a major challenge for sustainable development. About 4.1 million annual deaths have been attributed to excess salt/sodium intake. Globally, countries are focusing efforts to implement salt reduction initiatives in their frameworks, having a global target of 30% relative reduction in salt/sodium intake (WHO, 2014).

Salt is an essential ingredient in processed meat products; it is related to flavor, texture improvement, myofibrillar protein solubilization, and water activity (a_d) reduction, controlling pathogenic microorganisms growth and improving shelf life (Ruusunen & Puolanne, 2005). Therefore, salt reduction is especially challenging in processed meat industry. Different strategies have been studied to achieve salt reduction in meat products, such as its partial replacement and use of salt enhancers (Corral, Cano-García, Salvador, & Belloch, 2015; Corral, Salvador, Belloch, & Flores, 2015; Xiang, Ruiz-Carrascal, Petersen, & Karlsson, 2017). Several studies have shown satisfactory results in physicochemical, microbiological and sensory properties with approximately 40% sodium reduction when using salt replacement (Devlieghere, Vermeiren, Bontenbal, Lamers, & Debevere, 2017). However, the use of these salt replacers is limited due to the inferior technological characteristics compared to sodium chloride and the development of perceived off-flavors in the meat product (Gelabert, Gou, Guerrero, Antarn, & Arnau, 1996). However, the use of these salt replacers is limited due to the inferior technological characteristics compared to sodium chloride and the development of perceived off-flavors in the meat product (Gelabert, Gou, Guerrero, & Arnau, 2003; Terrell & Olson, 1981). On the other hand, the potential use of salt enhancers, such as yeasts, hydrolyzed vegetable protein, and others can themselves contain a salt level of up to 40%, and therefore, the amount used must be limited due to their contribution in the final total sodium of the product (Inguglia, Zhang, Tiwari, Kenny, & Burgess, 2017).

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Sodium reduction is especially challenging for existing products in the market. It is possible that consumers expect negative changes towards a product with lower levels of salt (Boon, Taylor, & Henney, 2010; Liem, Miremadai, Zandstra, & Keast, 2012). However, consumer food choices are affected only when the reduced-sodium products do not match the characteristics of the regular product (Zandstra, Lion, & Newson, 2016). The World Health Organization has recommended the implementation of progressive reductions in sodium content of foods with clear timelines to achieve lower sodium intake levels (WHO, 2018). This strategy allows consumers to adapt to lower sodium contents without being aware of the change, achieving targeted sodium contents gradually (Willems, van Hout, Zijlstra, & Zandstra, 2014).

Traditionally, sensory perception research on reduced-salt meat products is performed using hedonic or descriptive methods (Corral, Salvador, & Flores, 2013; Guárdia, Guerrero, Gelabert, Gou, & Amau, 2006; Tobin, O’Sullivan, Hamill, & Kerry, 2013). Nevertheless, when small changes are evaluated between food products, discrimination testing is recommended (Rousseau, 2015). This kind of tests has the advantage of not requiring the same level of expertise as descriptive analysis, neither a large number of subjects as in hedonic investigation. Moreover, it is ideal that consumers can not recognize the change in products subjected to salt reduction, matching the aim of discrimination testing. On the contrary, for descriptive analysis and consumer testing products should be distinguishable to describe product attributes and avoid consumers frustration by perceiving every product as the same (O’Mahony & Rousseau, 2003).

Implementation of gradual salt reduction initiatives requires a concentration reduction that consumers cannot perceive; consequently, estimation of difference thresholds could be a supporting tool to achieve this objective. Just noticeable difference (JND) represents the point at which change in concentration is starting to be noticed. Traditionally, JND is measured by the method of constant stimuli (a method of comparison to a constant reference), in which a series of products are raised and lowered around reference level. When a 2-Alternative Forced Choice (2-AFC) test is used, a constant stimulus and one lower or higher salt concentration are presented as a pair and the subject would be asked to choose which sample is stronger (in this case saltier). The difference threshold or JND is calculated from the psychophysical function. This means that the constant stimuli method resembles discrimination tests with the exception that the result is an interval estimation rather than a statistical significant difference (Lawless & Heymann, 2010).

Threshold methods are typically used in ingredient replacement for cost savings, regulatory requirements, or product modification, where the change must not be evident to the consumer (Rousseau, 2015). Stimuli used in discrimination methods are so similar that it is difficult to determine whether they are the same or different. Specifically, 2-AFC can be used when salt variations in product formulations cause subtle differences. Likewise, another advantage of this method is that requires consumer sampling, instead of trained assessors, resulting in less conservative and, therefore, more realistic salt reductions (Ishii, Kawaguchi, O’Mahony, & Rousseau, 2007).

On this context, the aim of this study was to show a fine-tuning approach to determine the JND in the sensory perception of reduced-salt meat products to achieve salt reduction without consumer awareness.

### 2. Materials & methods

#### 2.1. Ingredients and raw materials

Pork, beef and back fat were obtained from a local butcher. Isolated soy protein (Bremil, Brazil), potato starch (Emsland, Germany), salt (Sal Sol®, Costa Rica), sodium polyphosphate (Bundenheim corp, Germany), curing salt (6.25% nitrite) (Chemelco, Holland), sodium erythorbate (Zhengzhou TuoyangBio-Engineering Co, China) and bologna seasoning (Baltimore Spice, Costa Rica) were added ingredients.

#### 2.2. Meat products production

Three cured and cooked meat products (cooked sausage, fat-reduced cooked sausage and cooked chorizo) were selected to determine the just noticeable difference (JND) in sensory perception of salt reduction. Using a standardized production process, one batch of each product was made for both studies (Johansson, Drake, Pangborn, Barylko-Pikielna, & Köter, 1973; Lundgren, Pangborn, Barylko-Pikielna, & Daget, 1976; Masuoka, Hat Jopoulos, & O’Mahony, 1995), considering Sensory Evaluation type II, where the aim is to predict how well consumers can discriminate between different samples (O’Mahony & Rousseau, 2003). Table 1 shows a standard formulation to produce the three meat products. Salt concentration varied according to the threshold method explained below.

To produce cooked chorizo, lean pork meat and back fat were stored at 3–5°C prior use. Mincing was done using a mincer (Alfa-Laval, Kramer Grebe, Germany) and a perforated plate 10 mm hole. Temperature of the meat and back fat was controlled by cooling the equipment down with ice and keeping them at refrigeration temperatures before and after the process. Minced meat and back fat were weighed and mixed with the previously weighed dry ingredients. Mixing was performed manually until a well distribution of ingredients was observed. A second mincing was done using a perforated plate 5 mm hole. Mixture was stuffed in 160 mm diameter cellulose fibrous casings (Viscofan, Spain) using a manual stuffer, and resulted chorizos were labeled, weighed and cooked in steps as follow: 60°C for 30 min, 70°C for 30 min and 80°C until reaching 72°C in the cold spot, in order to assure product quality and safety.

| Table 1. Formulation of cooked sausage (CS), fat-reduced cooked sausage (FRS) and cooked chorizo (CC) using regular salt concentration, used as constant stimulus in threshold method. |
|-----------------|----------------|----------------|
| **Gr (%)**      | **CS (%)**     | **CC (%)**     |
| Minced beef trimmings | 22.8 | 22.8 | 19.3 |
| Mixed pork trimmings  | 22.8 | 22.8 | 33.8 |
| Back fat           | 14.2 | 10.7 | 19.3 |
| Potato starch      | 5.1  | 5.1  | 1.9  |
| Soy protein concentrate | 6.1  | 6.1  | 9.7  |
| Water             | 25.4 | 28.9 | 12.7 |
| Sodium nitrite1  | 0.02 | 0.02 | 0.02 |
| Sodium chloride   | 2.24 | 2.24 | 1.95 |
| Phosphate         | 0.4  | 0.4  | 0.4  |
| Sodium erythorbate| 0.08 | 0.08 | 0.08 |
| Spices            | 0.9  | 0.9  | 0.9  |

1. 0.6% NaNO2. Dosage complies with RTCA 67.04.54:10.
2. 0.6% NaNO2. La dosis cumple con el RTCA 67.04.54:10.
safety. Chorizos were immediately cooled down by immersion in water-ice bath until reaching minimum 30°C and, then, vacuum packaged (New Diamond Vac®, Jaw Feng Machinery Co, Taiwan) in labeled bags and stored at 3–5°C.

For production of both cooked sausages (Table 1), pork, beef meat and backfat were minced as explained previously and, then, processed in a previously chilled cutter (Hobart, USA) where particle size was reduced to obtain a fine paste. Then salt, polyphosphates, curing salt, sodium erythorbate and half of the water were added and homogenized for 1 min. Afterward, the rest of the water, potato starch, isolated soybean protein, and seasoning were added and homogenized for 1 more min. The whole emulsion process was carried out in the shortest time possible (≤6 min for each treatment) and without exceeding a final temperature of 10°C. The resulting fine paste was stuffed manually into polyamide casings (51 mm diameter), and cooking and chilling were done following chorizo procedure. Cooked sausages were packaged in labeled bags and stored at 3–5°C.

2.3. Participants

Two consumer studies were carried out for each of the cured meat products. One study was designed to find the difference threshold with 40 consumers and the second study involved other 40 consumers to compare the original (regular salt concentration) and the reduced-salt meat products (using the JND value found in the first study).

The 40 untrained consumers were chosen using a difference between samples corresponding to a d’ = 1 (value considered as threshold by Rousseau 2015), α = 0.05 and 95% power (Ennis, Rousseau, & Ennis, 2014; Rousseau, 2015), which means that if the difference exists it is possible to find it with a 95% power.

All participants were recruited based on their cured meat products consumption frequency and willingness to take part in the study. Participants signed an informed consent form, according to the Scientific Ethics Committee from the University of Costa Rica that reviewed and approved the sensory procedures (nº VI-4141-2014) and received a small gift for their participation.

Consumers who evaluated the three meat products were between 21 and 60 years old. Gender distribution was: 52.5% male and 47.5% female (regular cooked sausage), 35% male and 65% female (reduced-fat cooked sausage), and 30% male and 70% female (cooked chorizo).

2.4. Salt JND for meat products: first study

Based on sodium content from Costa Rican commercial sausages, the most frequent salt concentration was selected as the constant stimulus.

Human being sensory perception does not change linearly respect to physical intensity. Therefore, several psychophysics laws were developed to measure human being behavior. Weber, a German physiologist, developed a principle based on the ability of human beings to notice sensory differences only if a physical stimulus changes for more than a constant proportion of its actual magnitude (Reich, Tuffin, & Schatz, 2013). The Weber-Fechner law of perceived intensity states that sensory sense of magnitude is proportional to the logarithm of stimulus intensity (Johnson, Hsiao, & Yoshioka, 2002). Accordingly, lower and higher concentrations around the constant stimulus were calculated using a semi-logarithmic relation (a 1.85 factor for both cooked sausages and 1.80 for cooked chorizo) to achieve obvious sensation differences ranging from “barely perceived” to “extremely perceived”. Selected salt concentrations were: 0.52%, 0.80%, 1.32%, 2.28%, 4.06%, and the constant stimulus was 2.24% for both cooked sausages; while for cooked chorizo, concentrations were 0.50%, 0.73%, 1.15%, 1.90%, 3.25%, and 1.95% as the constant stimulus.

A preliminary bench testing with the regular and the five products with lower and higher salt concentrations than the regular salt product was performed using experienced assessors, in order to determine the degree and the nature of the difference between samples. Difference among texture was small between the lowest salt concentration and the regular salt sample. Flavor and taste changes were not perceived easily.

A 2-AFC test was used to determine the salt difference threshold for each meat product used in separate sensory panels (three sessions). A set of five pairs was presented to panelists. Each pair consisted of a constant stimulus sample and one sample of each salt concentration previously mentioned. Consumers were asked to choose the saltiest sample. Samples were presented in randomized and balanced order to the judges.

The lowest salt concentration was used as a primer before each pair. Panelists were asked to rinse their mouth with a 3% ethanol solution to dissolve fat, followed by a deionized water rinse to clean the palate. A 20 s waiting time was established between pairs of samples to generate saliva. This rinse protocol avoids adaptation and carry-over effects (Cubero-Castillo & Noble, 2001).

Meat product samples 1 cm thick were pan-fried at 60°C for 2.5 min each side and presented at room temperature to panelists.

2.5. Sensory difference between regular and reduced-salt meat products: second study

Once salt reduction was calculated for each meat product, a procedure was established to determine if consumers will not be able to perceive the difference against the original salt concentration.

Cooked sausage, fat-reduced cooked sausage, and cooked chorizo were made using regular and reduced-salt concentrations. Salt reduction was intended to be lower than JND, thus an arbitrary increase of salt was considered to formulate the reduced-salt sample. Since JND is the concentration in which consumers just start distinguishing the difference, a smaller reduction might avoid sensing a change in saltiness against an original product.

A preliminary bench testing with the regular and reduced salt products was performed again using experienced assessors, in order to determine the degree and the nature of the difference between the two samples. Among all possible attributes only saltiness presented a subtle intensity difference between stimuli, meaning this was the relevant attribute. Neither texture nor other flavors differed between samples during the bench testing. As the difference can be specified, a 2-AFC test was suitable (O’Mahony & Rousseau, 2003).

A 2-AFC test with 40 untrained consumers was performed (d’ = 1, α = 0.05 and 95% power), pairing the constant stimulus and a reduced-salt sample for each meat product (one pair per consumer). A primer corresponding to the reduced-salt sample (weakest sample) was used. Samples were presented in randomized and balanced order to the judges. Three sessions were performed, one per meat product.

Sample preparation and sensory panel were carried out following the same procedure as the first study.
2.6. Data analysis

The percentage of subjects who perceived the sample different from the constant stimulus as the saltier in 2-AFC was considered the correct response. Frequency of correct responses was plotted against salt concentration (%) using Microsoft Excel 2017®. Straight lines were fitted to a linear correlation (McBurney & Collings, 1977; Orellana-Escobedo et al., 2012; Pfaffmann, Bartoshuk, & McBurney, 1971) for cooked sausages. For cooked chorizo, a logarithmic correlation was plotted (Bobowski & Vickers, 2012; Rohm & Raaber, 1992). The difference threshold (JND) was determined by the concentration difference between the associated 75% and the 25% points in the frequency axis divided by two. In this study, for 2-AFC or paired comparison method, the probability of selection of a specific product (saltier), by chance alone, is one out of two (50%) (Boring, 1942; Lawless & Heymann, 2010; Viswanathan, Mathur, Gnyp, & St. Pierre, 1983). Once data were adjusted for chance, the perception zone is currently reduced between 50% and 100% frequency. For a 2-AFC test, the calculated 25% and 75% levels became 62.5% and 87.5% frequency axis (McBurney & Collings, 1977).

Second study data were analyzed with a one-tail binomial analysis using tables developed by Ennis et al. (2014) with α = 0.05 and 95% power to show if population could be able to perceive the difference between regular and reduced-salt meat products. Also, the real size of the difference (d') was estimated using the tables of probability of correct response as a function of d' (Ennis et al., 2014).

3. Results & discussion

3.1. Concentration-response curves: salt Just Noticeable Difference (JND) for three meat products

Figure 1 shows the psychophysical curves for each meat product and the mathematical correlation used to find the difference threshold value (JND).

Human beings’ sensory system is not a laboratory equipment in which a sample gives always the same answer and, regularly, the physical change is linearly proportional to the equipment response. Humans have adapted to perceived environment variations resulting in different sensory outputs, such as small sensory sensation produced by a high variation in physical magnitude or vice versa. Therefore, examination of concentration-response curves for a constant stimuli method is recommended, as it gives an idea of collected data’s quality. It is expected to have a sigmoidal shape (Foley & Matlin, 2015) called psychometric function (Boring, 1942). The response at levels below threshold should be around a baseline and then grow faster above threshold (Marin, Barnard, Darlington, & Acree, 2018). The function flattens out when it approaches a maximum response as all receptor sites are filled and saturated (Lawless & Heymann, 2010).

The psychophysical curves for cooked chorizo and two cooked sausages (Figure 1) fitted the expected S-shaped curve partially. Chorizo’s curve (Figure 1a) showed steep rise and final flat zones as expected. It also revealed that at least one smaller salt concentration was required to obtain the initial flat portion (baseline), that is absent in this curve. However, the most important part of the psychophysical curve is when it rises fast and reaches higher correct proportions on the receptor saturation zone, due to the fact that the difference threshold must be interpolated between the 62.5% and 87.5% points in the function (Lawless & Heymann, 2010). In this case, salt concentration range chosen allowed surpassing 90% correct responses. Thus, selection of stimulus concentrations is crucial to obtain a representative threshold value.

The two cooked sausages’ curves (Figure 1b) presented the baseline and steep rise zones characteristic of an S-shaped curve and both lacked the end flat zone representative of receptors saturation. Although more than 90% correct responses were achieved when the highest salt concentration was compared against the constant stimulus, end flat zone was missing, likely due to the need of a higher salt concentration to saturate the receptors. Again, the curves presented a fast-rising zone reaching a high correct response percentage that indicated that an interpolation could be calculated between the 62.5% and 87.5% points in the function.

Thresholds represent only 1 point on a dose–response curve or psychophysical function. The difference threshold (JND) represents the minimum physical change necessary in order for a person to sense the change 50% of the time (Boring, 1942), as mentioned in data analysis section. When data show a sigmoid psychometric function it must be linearized using z-scores transformation, logistic regression, probit or any other.

Figure 1. Psychophysics curve and correlation relating the percentage of subjects who chose the sample different from the constant stimulus (correct responses) as the saltier in 2-AFC against salt concentration compared for three meat products: regular fat cooked sausage (CS), fat-reduced cooked sausage (FRS) and cooked chorizo (CC).

Figura 1. Curva psicofísica, y correlación, que relaciona el porcentaje de sujetos que escogen la muestra diferente al estímulo constante (respuestas correctas) como el más salado en la prueba de discriminación 2-AFC con respecto a la concentración de sal, para los tres productos carnícos: salchichón (CS), salchichón reducido en grasa (FRS) y chorizo cocido (CC).
between regular and reduced-salt chorizo ($p = .21$) nor both types of cooked sausages ($p = .32$ and $p = .21$). Therefore, consumers will not be able to perceive salt reduction achieved using JND methodology. Since samples did not differ, it is not recommended to use scaling techniques, such as acceptability tests. In other words, if both samples are perceived the same consequently their liking should be the same (Lawless & Heymann, 2010; O’Mahony & Rousseau, 2003). These results are Trustful because 2-AFC test used was designed to guarantee that if a difference existed, it would be perceived. O’Mahony and Rousseau (2003) explained that 2-AFC tests is statistically one of the most powerful discrimination methods, compared to triangle and duo-trio tests, this means that using same test power, 2-AFC requires smaller sample sizes for detecting a given degree of difference (O’Mahony, Masuoka, & Ishii, 1994). Total salt reductions obtained for the three meat products were between 18.5% and 22% (Table 3).

Few studies have carried out salt reduction taking into account threshold methodology and none, to our knowledge, evaluated meat products (Antuñez, Giménez, & Ares, 2016; Orellana-Escobedo et al., 2012). Besides, some studies have evaluated salt reduction in foods using consumers to measure sensory attributes and acceptability; however, lack of experience, vocabulary and consumers’ concept alignment prevents generation of quality descriptive data (Ishi et al., 2007). Instead, to generate a sensory profile, the use of trained panelists is recommended.

Accordingly, some authors used trained panels to evaluate salt reduction effect on sensory characteristics without being able to recommend specific values accepted by consumers, because results are sensory profiles and not hedonic values (Aslyng, Vestergaard, & Koch, 2014; Jüdl, Saláková, Müllerová, & Kozohorská, 2018). Aslyng et al. (2014) found that a 23% reduction in added salt did not detrimentally affect saltiness or any other sensory attributes. Again, this reduction was not evaluated for its consumer’s acceptance. Ruusunen, Sarkka-Tirkkonen, and Puolanne (1999) evaluated pleasantness and saltiness of several salt concentrations on ‘bologna-type’ sausages resulting in a potential salt reduced concentration (from 1.95% to 1.35%, meaning 30% reduction); yet, this value did not reflect consumers’ degree of liking. Again, Cluff, Kobane, Bothma, Hugo, and Hugo (2017), did not find significant differences in acceptability of bologna sausage with small salt concentration changes, using a 9-point hedonic scale. In spite of not finding a difference between regular and reduced-salt meat products, the abovementioned studies used rating scales which only discriminate among easily discriminable stimuli (O’Mahony & Rousseau, 2003). Therefore, in these studies salt reduction values might be perceived and rejected by consumers (Zandstra et al., 2016).

Commonly used sensory approaches to determine differences in reduced-salt meat products (rating scales in descriptive analysis or in consumer hedonics), might not be as powerful and precise as discrimination testing methods (O’Mahony & Rousseau, 2003). Therefore, discrimination tests are a better approach to find very small salt taste differences giving that consumers will not be able to perceive those and, consequently, prevent rejection of reduced-salt products. Combining discrimination tests with a threshold method of constant stimuli have the advantage to provide a value that was not necessarily evaluated because it could be extrapolated from data.
The hypothesis that reducing salt less than JND value would not be noticed by consumers was proved based on d’ values. A d’ of 1 represents the threshold value, which means that consumers just start perceiving the difference (O’Mahony & Rousseau, 2003). In the present study, the d’ values were less than 0.27 (Table 3), meaning that if saltiness is the relevant attribute to be discriminated, the difference among other attributes would be even more difficult to find. These very small d’ values indicate that consumers were unable to find overall difference between the salt reduced concentration compared to the regular high salt concentration.

The achieved percentage of salt reduction might still be regarded as conservative considering that consumers in a real-life setting would not evaluate two samples one right after the other. Instead, they would compare reformulated products with their memory of the regular product sensory characteristics (Antúnez et al., 2016).

Furthermore, considering that replacing salt is expensive for food industry as salt is one of the cheapest food ingredients available and replacers have higher costs, the more appropriate approaches prefer reduction rather than substitution. A 20–30% salt reduction will increase costs of materials by 5% to 30% when salt replacers are used (Kloss, Meyer, Graeve, & Vetter, 2015), but a reduction of 18.5–22%, that is not perceived by consumers, will not have an extra cost, as long as shelf life of the product is not affected.

Having this important reduction, it is worth pointing out some improvements. Microbiological and physicochemical stability might be affected during storage; therefore, the reduced salt product obtained requires microbiological and shelf life studies to ensure product quality and commercialization feasibility. Second, a descriptive analysis of the samples might be conducted to include the evaluation of other attributes (wholeness, flavor, aroma, etc.), in order to know the complexity of the sample and assure that only saltiness was affected by the salt reduction. Third, although there are no publications reporting a definite physiological difference between men and women on sensory evaluations and there are contradictory results on gender sensitivity (Hayes, Sullivan, & Duffy, 2010; Hyde & Feller, 1981; Lehrner, 1993; Velle, 1987), the difference between female and male share in the evaluation of each product might be a limitation of this study. Thus, this is an interesting topic for future research in sensory sciences.

4. Conclusions

Through this study it is demonstrated that a 18.5% to 22% salt reduction in three meat products is possible without consumer’s awareness, using the constant stimuli threshold method. Discrimination methods required fewer skills from consumers and results show to be more accurate than other sensory methods especially when an unnoticeable change is attempted. Furthermore, this fine-tune methodology allows to find small sensory changes when salt is reduced.

The gradual salt reduction approach has been highly recommended in literature. Although this gradual approach for long-term programs usually starts with an arbitrary salt percentage value that could be too conservative and its usefulness could be questionable. The JND value is suggested to complement this gradual reduction program to achieve more accurate and higher salt changes with the advantage that consumers will not perceive the difference between each step.

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