Impact of iodized table salt on the sensory characteristics of bread, sausage and pickle

Greis, M

2018-07

Greis , M , Seppa , L , Venalainen , E R , Lyytikainen , A & Tuorila , H 2018 , ' Impact of iodized table salt on the sensory characteristics of bread, sausage and pickle ' , Lebensmittel - Wissenschaft und Technologie , vol. 93 , pp. 606-612 . https://doi.org/10.1016/j.lwt.2018.04.009

http://hdl.handle.net/10138/237875
https://doi.org/10.1016/j.lwt.2018.04.009

Accepted Manuscript

LWT – Food science and technology impact of iodized table salt on the sensory characteristics of bread, sausage and pickle

Maija Greis, Laila Seppä, Eija-Riitta Venäläinen, Arja Lyytikäinen, Hely Tuorila

PII: S0023-6438(18)30315-3

DOI: 10.1016/j.lwt.2018.04.009

Reference: YFSTL 7020

To appear in: *LWT - Food Science and Technology*

Received Date: 1 November 2017

Revised Date: 3 April 2018

Accepted Date: 4 April 2018

Please cite this article as: Greis, M., Seppä, L., Venäläinen, E.-R., Lyytikäinen, A., Tuorila, H., LWT – Food science and technology impact of iodized table salt on the sensory characteristics of bread, sausage and pickle, *LWT - Food Science and Technology* (2018), doi: 10.1016/j.lwt.2018.04.009.

LWT – Food Science and Technology

Impact of iodized table salt on the sensory characteristics of bread, sausage and pickle

Maija Greis [ab*], Laila Seppä[a], Eija-Riitta Venäläinen[c], Arja Lyytikäinen[cd], Hely Tuorila[a]

[a] Department of Food and Nutrition, P.O.Box 66, FI - 00014 University of Helsinki, Finland

[b] Present address: Valio Ltd, Meijeritie 4, 00730 Helsinki

[c] Finnish Food Safety Authority, Evira, Mustialankatu 3, 00790 Helsinki

[d] National Nutrition Council, Mustialankatu 3, 00790 Helsinki

*Corresponding author. Tel. +358 44 3854344, E-mail address: maija.greis@valio.fi

LWT – Food Science and Technology

Impact of iodized table salt on the sensory characteristics of bread, sausage and pickle

Maija Greis [ab*], Laila Seppä[a], Eija-Riitta Venäläinen[c], Arja Lyytikäinen[cd], Hely Tuorila[a]

[a] Department of Food and Nutrition, P.O.Box 66, FI - 00014 University of Helsinki, Finland

[b] Present address: Valio Ltd, Meijeritie 4, 00730 Helsinki

[c] Finnish Food Safety Authority, Evira, Mustialankatu 3, 00790 Helsinki

[d] National Nutrition Council, Mustialankatu 3, 00790 Helsinki

*Corresponding author. Tel. +358 44 3854344, E-mail address: maija.greis@valio.fi

Abstract

The impact of iodized table salt on the sensory quality of wheat bread, bologna sausage and pickled cucumber was studied. Table salt (NaCl) content of the products was 1.7, 1.2 and 1.7 g/100 g, respectively. Iodine, added as potassium iodide (KI), was incorporated at levels 0, 25, 50 and 100 mg per kg table salt. Odor, flavor, appearance, and texture were evaluated using deviation from reference descriptive analysis (12 panelists, 4 replicates). Each sample was rated against the non-iodized reference sample (0 mg iodine). The retention of iodine during processing and storage was determined chemically. The iodine level 25 mg/kg, corresponding to current recommendations, did not cause sensory changes in tested products. In sausage, 50 and 100 mg/kg levels were associated with minor changes in texture and color. The maximum retention of iodine was 83% for bread, 98% for sausage, and 51% for cucumber. We did not find any sensory obstacle to using iodized table salt in industrial food production. Due to loss in manufacturing and inadequate intakes, iodine additions higher than currently recommended should be considered.

Keywords: fortification, iodized table salt, iodine retention, sensory quality

1. Introduction

The World Health Organization estimates that globally around one third of the world's population has inadequate iodine intake (WHO, 2004). Iodine status in developed countries shows a decreasing trend (SCF, 2003; Winger, König, & House, 2008). In Finland, the National Nutrition Council (NNC) recommends industrial use of iodized table salt, due to the mild iodine deficiency observed at the population level (NNC, 2015). According to NNC, the deficiency is partly due to the usage of non-iodized salt in food industry, as increased consumption of industrially manufactured food has replaced home-made savory foods that usually contain iodized salt.

The most common iodine salts to be added to food are potassium iodate (KIO_3) or iodide (KI). Fortification levels differ substantially. The range in Europe is from 8 to 69 mg iodine per kg of table salt (NaCl). The typical level of iodine is 20–25 mg/kg NaCl. Netherlands and Greece have one of the highest iodine contents in table salt in Europe, 50 mg per kg, added as KI (Winger et al., 2008). Charlton and Skeaff (2011) report that in some African countries, for example in Kenya, table salt contains iodine 100 mg/kg NaCl as KIO_3.

Food manufacturers are concerned that iodized table salt may impact the sensory quality of their products (Harris, Jooste, & Charlton, 2003). Many food companies were not willing to use iodized table salt for reasons such as increased costs, instability of iodine and misconceptions regarding iodine (Ohlhorst, Slavin, Bhide, & Bugusu, 2012). West, Merx, and de Koning (1995) concluded that food industry is worried about the darkening of color in iodized products.

Previous studies examining the effect of iodized salt on the sensory properties were conducted a relatively long time ago, and the methods used may not be appropriate or sensitive enough for detecting subtle differences between iodized and non-iodized samples. For example, several studies use hedonic ratings for comparison among iodized and non-iodized samples (Kojima & Brown, 1955; Amr & Jabay, 2004; Chanthilath, Chavasit, Chareonkiatkul, & Judprasong, 2009; Pinkaew & Karrila, 2015). Kuhajek and Fiedelman (1973) found no effect of iodized salt in bread, potato chips and sausage. Similarly, Wirth and Kühne (1991) did not find sensory differences between iodized and non-iodized meat products (iodine added as KIO_3 0.3–0.6 mg/kg of curing salt). On the other hand, Winger et al. (2008) detected small differences in the flavor of tomato juice at high iodine level (200 mg/kg tomato juice) compared to the typical iodine content (25 mg/kg NaCl). Amr and Jabay (2004) observed softening of texture and lowering of color scores in pickled vegetables when 40 mg/kg NaCl as KIO_3 was added. Pinkaew and Karrila (2015) found higher hedonic scores in iodine, iron and zinc fortified fish crackers compared to non-fortified crackers. Iodine was added as KIO_3 (0.26 mg/100 g dough). Also Chanthilath et al. (2009) found no significant differences in fermented fish sauce prepared with non-iodized and iodized salt (iodine as KIO_3 at 30 mg/kg NaCl).

Most studies related to iodine fortification focus on the loss of iodine (Goindi, Karmarkar, Kapil, & Jagannathan, 1995; Chavasit, Malaivongse, & Judprasong, 2002; Waszkowiak & Szymandera-Buszka, 2008; Comandini, Cerretani, Rinaldi, Cichelli, & Chiavaro, 2013). According to Chavasit et al. (2002) cooking method or pH value did not have an effect on iodine loss for a range of foods, but addition of sugar, table salt, phosphoric or ascorbic acid lowered iodine content in different foods. Cooking increased the loss of iodine compared to steaming (Goindi et al., 1995), while carrots and potatoes did not absorb iodine during boiling but iodine was better absorbed during baking in these products (Comandini et al., 2013).

This study examined whether, and to what extent, the addition of iodine to table salt has an impact on the sensory characteristics of selected savory products. The materials were wheat bread, bologna sausage and pickled cucumbers. Bread and sausage were included because they are major sources of NaCl in the Finnish diet (Borodulin et al., 2013). Pickle was selected as the results by Amr and Jabay (2004) suggested changes in color and texture due to iodized salt. Iodine was added to each material 0 mg, 25 mg, 50 mg, and 100 mg per kg NaCl. Twenty-five mg per kg NaCl is the level recommended in Finland (NNC, 2015). The 50 and 100 mg were examined as they are typical iodine levels in certain countries. In addition, the iodine content of these foods was studied with chemical analysis. We hypothesized that iodine fortification does not impact the sensory quality of tested products.

2. Materials and methods

Each material, bread, sausage and pickle, was prepared at four iodine levels referred to as batches. The examined iodine levels 0, 25, 50, and 100 mg iodine per kg NaCl in each material are referred to as 0 mg/kg, 25 mg/kg, 50 mg/kg, and 100 mg/kg.

2.1. Chemicals

KI used in this study was from Sigma (Sigma-Aldrich, Helsinki, Finland) and NaCl from Berner Ltd (Helsinki, Finland). NaCl purity level was 99.8% and it contained sodium ferrocyanide (E353) as anticaking agent.

The ultrapure water was obtained from a Milli-Q-system (Millipore Corporation, Bedford, MA, USA). Ammonium hydroxide 4.6 g/L was prepared from 182 g/L ammonium hydroxide (BDH, Prolabo, Normatom for trace metal analyses). The iodide stock standard solution (KI in H_2O) was from Romil (Cambridge, GB) and the tellurium stock standard solution (H_6TeO_8 in HNO_3) from Merck (Germany), both 1000 mg/L.

For iodine determination 0.1, 0.2, 0.5, 2.5, 5.0, 10, 20 µg/L standard solutions were prepared from the iodine stock solution in 4.6 g/L ammonium. Tellurium was used as internal standard at a concentration of 1 mg/L and was prepared from tellurium stock solution in H_2O. Iodine isotope 127 was used for determination of iodine. The LOQ was 0.060-235 mg/kg.

2.2. Salt and brine preparation

A stock solution was used to add the iodide (KI). In bread and sausage preparation, the brine containing NaCl, KI and water was prepared for each batch. In pickle preparation the iodine (as KI solution) and NaCl were added separately to the pickle juice.

Of the stock solution (bread 9.9, sausage 0.8, cucumber 5.1 g KI/L water) 10–40 mL was added into Milli-Q water and filled to 1 liter. Added KI content was tied to the NaCl level in each batch (Table 1). According to the labeling, the NaCl concentrations of bread and sausage were 1.7 g/100 g and 1.2 g/100 g, respectively. In the pickle juice NaCl concentration was 4.0 g/100 g and in cucumbers 1.7 g/100 g.

2.3. Preparation of samples

2.3.1. Wheat bread

The ingredients of the bread were wheat flour, rye flour, yeast, wheat gluten, vegetable oil, potato flour, rye malt, emulsifier (E471), acidity regulator (E270), ascorbyl palmitate (E304), NaCl and KI. In bread, the dietary fiber content was 3.5 g/100 g. Bread was prepared in a factory scale in 4 batches by a bakery company Vaasan Oy (Helsinki, Finland). For each level of KI, 200 kg of dough was prepared. The bread was baked in the oven (236ºC–273ºC) for 22 min. The bread loaves were sliced, and the next day they were stored in freezer for 5 days in –18ºC. The bread was thawed for three h before the evaluations.

2.3.2. Bologna sausage

The ingredients of the sausage were pork, beef, pork fat, water, ice, phosphate mixture, ascorbate (E301), nutmeg, white pepper, coriander, nitrite solution, and the brine containing NaCl and KI. In sausage, the meat content was 74 g/100 g. Four 15 kg batches were prepared in a pilot plant scale at the Department of Food and Nutrition, University of Helsinki, Finland. The meat was ground in a cutter in two 30 kg batches which were both divided into two 15 kg batches and ground again before adding other ingredients. The mass was stuffed in to fibrous casing prior boiling the sausages for 70 min to an internal temperature of 72ºC (RH 100%). The sausages were packed in vacuum and stored at 5ºC for 9 days before sensory evaluation.

2.3.3. Pickle

The ingredients in the pickle juice were water, vinegar, NaCl, sugar, dill aroma and KI. Four batches of pickle were prepared in a pilot plant of Orkla Foods Oy (Turku, Finland). For each batch, 40 liters of pickle juice was prepared.

Cucumbers were sliced (6.4 mm thick) and put into glass jars (370 g cucumbers per 500 mL jar). The solution of water, KI and NaCl was heated up to 35°C prior to adding sugar. The sugared pickle juice was heated up to 62°C and dill aroma and vinegar were added. The jars were filled with the pickle juice (175 mL), sealed and pasteurized (70°C for over

15 min). The pickles were stored at room temperature for 38 and 69 days before sensory evaluation.

2.4. Panelists

The sensory panels for each material were recruited from the Department (staff and students). The panels for bread, sausage and pickle were partially different. Each panel consisted of 12 members (10-11 women, 1-2 men) aged 21-54 years (mean 32 years, median 29.5 years). Five panelists served in all three panels, six panelists in two, and the remaining nine in one panel. The development of the vocabulary and evaluation techniques was carried out by preliminary panels consisting of 8 to 12 members who attended the sensory evaluations of the respective product. Prior to entering the panel, ability to identify basic tastes was tested and found normal (ASTM STP-758, 1981; ISO, 2012) in all the panelists. The study followed the ethical requirements of the sensory laboratory approved by the University of Helsinki Ethical review board in humanities and social and behavioral sciences, and an informed consent was signed by the panelists.

2.5. Procedure

The lexicon used for each material was compiled with a preliminary panel. The panelists compared individually the reference sample (0 mg iodine) and the sample with the highest content of iodine (100 mg/kg). They suggested and approved the descriptors and their definitions in group discussions. An attribute was included in the lexicon when even a slight suggestion for a difference was expressed, to be sure that even the smallest changes could be detected (Table 2). References, if possible, were proposed and agreed. Subsequently, all 12 panelists in the final panel assigned for each sample type trained the attributes, descriptions, and evaluation techniques in two sessions in which the samples 0 mg/kg and 100 mg/kg were compared.

The method used, deviation from reference method (Lawless & Heymann, 2010) has a reference sample R (0 mg iodine) against which all other samples are evaluated. The non-iodized sample was included as a hidden sample and served as a reliability check of the ratings. Flavor, odor, texture and appearance characteristics were rated for intensity on an unstructured 10-cm line scale with the anchors: “less” and “more” or in the middle “as R”, equaling to the sample R. For sausage and bread, each evaluation was repeated four times (n=4*12). The pickles were analyzed after five and nine weeks following the preparation, with two replications each time.

In bread evaluation, there were three slices of bread of each batch. In sausage evaluation there were four slices of each sausage and in pickle evaluation, five slices of cucumber and 20 mL of pickle juice of each batch. The samples were coded with three-digit numbers and their order was randomized for each assessor. Evaluations were conducted in individual booths at room temperature with FIZZ Sensory Evaluation Software, Version 2.45 (Biosystemes, Courternon, France). Panelists were instructed to cleanse their palates with tap water between the samples.

2.6. Instrumental measurements

2.6.1. Determination of iodine concentration

The iodine level was determined in triplicate: In bread after storage for 36 days in –18°C, in sausage after 56 days in –18°C and in both cucumber and pickle juice, separately, after storage for 38 and 69 days at room temperature.

The samples were homogenized and microwave digested (bread, sausage, pickle) (Milestone Ethos Plus-2, Chelton, CT, USA) or extracted (pickle juice). Approximately 0.1 g of solid samples was weighed into digestion vessel and 1.25 mL of 182 g/L ammonium hydroxide and 10 mL of Milli-Q water was added. The samples were microwave digested as follows: ramping time 5 min at 200°C with power of 1000 W, holding time 15 min at 200°C and cooled down time 10 min. Digested sample was transferred into a 50 mL volumetric flask, 500 µL of internal standard was added and the volume filled to 50 mL with Mill-Q water.

Approximately 0.3 g of pickle juice was weighed into a 50 mL volumetric flask and 4.6 g/L ammonium hydroxide was added until almost full and shaken. On the following day, 500 µL of internal standard was added and the volume was made with 4.6 g/L ammonium hydroxide up to 50 mL. Samples were shaken for two h with 200 rpm and filtered with 0.2 µm syringe-type filter into auto sampler tubes.

Iodine concentrations were analyzed by inductively coupled plasma mass spectrometer, ICP-MS (Thermo Scientific X-Series 2, Waltham, MA, USA), which is accurate method compared to the previous methods (Winger et al., 2008). The detection levels in ICP-MS method for iodine are lower than the detection levels in other methods (Yebra & Bollain, 2010). Finnish Accreditation Service FINAS has accredited the method according to the standard SFS-EN ISO/IEC 17025.

2.6.2. Other measurements

The stability and similarity of the four batches was measured by triplicate pH measurement either during the preparation (dough and sausage mass) or after the storage (pickle juice). Cooking loss and water holding capacity (WHC) (Grau & Hamm, 1957) for sausage were determined by 3 (sausages) x 4 measurements and tenderness (Instron 4466, United Kingdom) by 3 (sausages) x 3 measurements. Brix (^{o}Bx) values were determined during the pickle juice preparation with a refractometer.

2.7. Statistical analysis

The sensory ratings were analyzed in relation to the reference sample R with t-test and Bonferroni adjustment in SPSS (SPSS 18.0, PASW Statistics, Chicago, IL, USA). Repeated two-way analysis of variance was conducted to investigate the consistency of ratings (4 iodine levels, 4 replicates [4 x 4]). In pickle, the two storage periods with two replicates were included in the analyses [4 x 2 x 2]. Statistically significant results at $p < 0.05$ are reported.

One-way analysis of variance was performed on cooking loss, tenderness and WHC in sausage, and Tukey’s test was applied when significant differences were observed.

3. Results

3.1. Sensory characteristics

The observed sensory changes due to iodine addition were small, if any, compared to the sample R (Figure 1). On the scale from –5 to +5 (0 representing similarity to sample R), the largest mean deviation from sample R was observed in color intensity and tenderness ratings of sausage (–0.7 and +0.4). The deviation of the hidden reference from the sample R was small in all cases, confirming the reliability of ratings.

No significance differences between the breads with iodine levels 0–100 mg/kg compared to sample R were found. Analysis of variance showed no significant differences for bread samples, replicates or samples x replicates in any of the attributes evaluated.

In sausage, the samples containing 50 mg/kg was more tender ($t(47) = 3.1$, $p = 0.004$) and less intense in color ($t(47) = –5.8$, $p < 0.001$) than sample R. Likewise, the tenderness of the sample 100 mg/kg was significantly higher ($t(47) = 2.6$, $p = 0.01$). Color intensity ($t(47) = –5.7$, $p < 0.001$) and odor intensity ($t(47)= 2.7$, $p = 0.009$) were significantly weaker than in sample R. Analysis of variance indicated a difference among the samples in tenderness ($F(3,33) = 6.6$, $p = 0.003$) and color intensity ($F(3,33) = 16.4$, $p < 0.001$. No significant effect of replicate or interaction of sample x replicate was found.

For pickle, no significant difference between the samples was found in any sensory attribute nor between storage times (5 and 9 weeks).

3.2. Iodine concentrations

The retention of iodine varied among the foods (Table 3). In bread, the retention was 76–83%, in sausage 86–98% and in cucumbers the retention was 49–51%. Five weeks after the preparation the iodine content was at the same level in pickle juice and in cucumbers, but at nine weeks, pickle juice appeared to have lost more than the cucumber.

3.3 Other measurements

Cooking loss, firmness and WHC are presented in Table 4. The only significant difference among the batches was in cooking loss [$F(3.24) = 4.1$; $p = 0.017$], with a significant difference between 0 and 100 mg/kg ($p = 0.013$). Cooking loss was higher in samples with higher iodine content. Tenderness and WHC did not differ between the samples.

In the bread dough, pH was 5.5–5.6, and acid value 4.9–5.1. In sausage mass pH was 5.8–6.0 and in cooked sausage it was 6.2–6.3. In pickle juice Brix was 15.9–16.4%. After 5 weeks of storage pH in the pickle juice was 3.3 and after 9 weeks it was 3.5–3.6.

4. Discussion

4.1. Sensory changes

The recommended iodine content in table salt, 25 mg/kg, did not result in sensory changes in iodized products compared to the non-iodized products. In bread and pickle, no difference between iodized and non-iodized samples was observed at higher levels (50 or 100 mg/kg) either.

Table salt has been used in bread for a long time as an iodine carrier, but little scientific research on the impact of iodized table salt on the sensory quality of bread has been reported. Consistently with the present results, Kuhajek and Fiedelman (1973) did not detect flavor or color changes in white bread at the level of added iodine 77 mg/kg NaCl.

The sausage containing iodine 25 mg/kg did not differ from the sample R. Kuhajek and Fiedelman (1973) found no sensory changes in liver sausages containing KI (77 mg/kg NaCl) compared to non-iodized sausages. Wirth and Kühne (1991) did not detect sensory differences between iodized (KIO_3) and non-iodized meat products either. We found a significant difference in texture and color at 50 and 100 mg/kg levels of iodine. Although significant, the mean deviation from reference was slight in both cases. It is unlikely that a consumer would notice such minor differences observed here by a trained panel in the presence of a reference sample that facilitates the detection of a difference (Lawless & Heymann, 2010).

The cooking loss from sausage increased with increased iodine level. This is possibly due to weakened WHC (Kauffman et al., 1993) of the sausage. A decrease in WHC was also observed although non-significantly. WHC is known to affect the color and softness of meat (Puolanne & Peltonen, 2013). Sausage mass was prepared in two batches, and the temperature was carefully followed during preparation. Thus, everything was done to minimize the differences between the batches of sausage mass so that the iodine content was the only divider between the four batches. Yet, more research is needed to examine the association between iodine and cooking loss or WHC.

Iodine content up to 100 mg/kg did not have an impact on the sensory attributes of pickle. Kojima and Brown (1955) found no sensory changes in canned corn, beans or sauerkraut to which iodine was added as KI at iodine levels of 92 mg/kg NaCl. These results are different from the study by Amr and Jabay (2004), who observed that KIO_3 at iodine level of 40 mg/kg NaCl led to darkened color and softened texture of pickled cucumber during short storage time (12 days). The results by Amr and Jabay (2004) might be due to the iodine compound (KIO_3) or short storage time. The differences between the samples of pickled vegetable might even out by the longer storage time.

4.2. Iodine retention

The iodine retention varied depending on the type of food. The preparation method and ingredients can affect the iodine retention (Comandini et al., 2013).

In bread, iodine retention was 76–83% and did not differ between the batches. The higher iodine loss in bread, compared to sausage and cucumber, might be due to longer period in high temperature in oven where iodine has more time to react with other compounds and evaporate. The loss of iodine seems to be higher for KI than for KIO_3 (Coumes, Vargas, Chopin-Dumas, & Devisme, 1998). These authors also found that KIO_3 is more stable in higher temperatures than KI. Such loss could be compensated by using higher concentrations of KI which, in the present study, did not change the sensory attributes of bread.

In sausage, the retention of iodine was 86–98%. Wirth and Kühne (1991) estimated that the iodine loss in sausage would be 20–30%. The iodine determination method in their study was not as accurate as the method we used (IGN, 2007). A method that cannot detect low iodine content might give an impression of high iodine loss. Also, cooking time and the presence of nitrite in the sausages could have had an impact on the retention of iodine (Coumes et al., 1998).

In pickle, iodine may have evaporated by reacting with acetic acid. Low pH, spices, sugar and additives are known to decrease iodine content (Chavasit et al., 2002); thus, the presence of sugar and acetic acid may have accelerated the loss of iodine in cucumbers.

After five weeks, the iodine content had divided evenly between cucumbers and pickle juice. The total loss of iodine increased slightly from five to nine weeks. By then the iodine had disappeared mainly from the pickle juice as the iodine content was higher in cucumber than in pickle juice. The relatively high iodine loss might be due to the soft skin of cucumbers and the consequent ease of salt penetration by osmosis.

4.3. Reliability of the sensory method

Previous literature on the effect of iodine on sensory quality has used triangle tests (Wirth & Kühne, 1991) and hedonic methods (Kojima & Brown, 1955; Amr & Jabay, 2004; Chanthilath et al., 2009; Pinkaew & Karrila, 2015). These methods do not indicate how much and in what way the samples differ from each other (Lawless & Heymann, 2010). Moreover, samples with dinstinctively different sensory attributes can receive fully identical hedonic scores, for which reason hedonic or acceptability ratings are inappropriate in analytical sensory work.

Deviation from the reference method is highly analytical and has been found to be more sensitive for testing small differences than, for example, the general quantitative descriptive analysis (Larson-Powers & Pangborn, 1978). It is sensitive, because each sample is compared against the reference sample R, and it allows the assessment of reliability through the hidden sample R. In the present study, the hidden sample R was rated similar to the reference sample R, thus indicating the high level of panel performance.

5. Conclusion

The commonly used and recommended iodine level 25 mg/kg per kg of table salt did not result in sensory changes in bread, sausage or pickle. The tested products represent a broad range of food products that differ in composition, manufacture and storage time. However, further research is warranted. Other relevant food products high in NaCl, should also be tested for sensory quality and iodine stability. Given the loss of iodine during the manufacturing and the recommendation to decrease the intake of salt (NNC, 2015; WHO, 2012), increasing iodine content in table salt should be considered. This would be an effective way to increase iodine intakes at the population level without increasing the consumption of table salt.

The findings should encourage food industry to use iodine fortification in savory products. More research is needed in iodine retention and absorption for effective prevention and control of iodine deficiency.

Acknowledgements

Dr. Marika Lyly (Vaasan Ltd), Pekka Kahila, MSc, (University of Helsinki) and Dr. Tarja Aro (Orkla Ltd) are gratefully acknowledged for arranging and supervising the preparation of the samples. Laboratory Engineer Soili Nikonen (Chemistry Research Unit, Evira) is thanked for the laboratory analyses of iodine. This study was funded by The Finnish Food and Drink Industries' Federation.

References

Amr, A.S., & Jabay, O.A. (2004). Effect of salt iodization on the quality of pickled vegetables. *Journal of Food Agriculture and Environment*, 2, 151-156.

ASTM STP-758 (1981). *Guidelines for the selection and training of sensory panel members*. Philadelphia: American Society for Testing and Materials.

Borodulin, K, Levälahti, E; Saarikoski, L, Lund, L, Juolevi, A, Grönholm, M.,…Vartiainen, E. (2013). The National FINRISK Study [Kansallinen FINRISKI 2012 – terveystutkimus; in Finnish]. National Institute for Health and Welfare, Report 22. Tampere: Suomen Yliopistopaino Oy. 130 p. URN:ISBN:978-952-302-053-5 Accessed 24 March 2018.

Charlton, K., & Skeaff, S. (2011). Iodine fortification: why, when, what, how, and who? *Current Opinion in Clinical Nutrition and Metabolic Care,* 14, 618-24.

Chanthilath, B., Chavasit, V., Chareonkiatkul, S., & Judprasong, K. (2009). Iodine stability and sensory quality of fermented fish and fish sauce produced with the use of iodated salt. *Food and Nutrition Bulletin, 30*, 183-188.

Chavasit, V., Malaivongse, P., & Judprasong, K, (2002). Study on stability of iodine in iodated salt by use of different cooking model conditions. *Journal of Food Composition and Analysis,* 15, 265-76.

Comandini, P., Cerretani, L., Rinaldi, M., Cichelli, A., & Chiavaro, E. (2013). Stability of iodine during cooking: investigation on biofortified and not fortified vegetables. *International Journal of Food Sciences and Nutrition,* 64, 857-861.

Coumes, C.C.D., Vargas, S., Chopin-Dumas, J., & Devisme, F. (1998). Reduction of iodine by hydroxylamine within the pH range 0.7-3.5. *International Journal of Chemical Kinetics,* 30, 785-797.

Goindi, G., Karmarkar, M., Kapil, U., & Jagannathan, J. (1995). Estimation of losses of iodine during different cooking procedure. *Asia Pacific Journal of Clinical Nutrition*, 4, 225-227.

Grau, R., & Hamm, R. (1957). Water holding capacity of mammal muscles [Über das Wasserbindungsvermögen des Säugetiermuskels. II. Mitteilung. Über die Bestimmung der Wasserbindung des Muskels; in German]. Zeitschrift für Lebensmittel-Untersuchung und –Forschung, 105, 446-460.

Harris, M., Jooste, P., & Charlton, K.E. (2003). The use of iodised salt in the manufacturing of processed foods in South Africa: bread and bread premixes, margarine, and flavourants of salty snacks. *International Journal of Food Sciences and Nutrition,* 54, 13-19.

IGN. Iodine Global Network. (2007). Final report Review of use of iodized salt in processed foods. Executive summary. http://www.iccidd.org/cm_data/Salt_in_processed_foods.pdf Accessed 24 March 2018.

ISO. (2012). *Sensory analysis - General guidelines for the selection, training and monitoring of selected assessors and expert sensory assessors*. International Standard. 8586-1. ISO, Geneve, Switzerland.

Kauffman, R., Sybesma, W., Smulders, F., Eikelenboom, G., Engel, B., Van Laack, R.,…van der Wan, P.G. (1993). The effectiveness of examining early post-mortem musculature to predict ultimate pork quality. *Meat Science,* 34, 283-300.

Kuhajek, EJ., & Fiedelman, H.W. (1973). Nutritional iodine in processed foods. *Food Technology,* 27, 103-107.

Larson-Powers, N., & Pangborn, R. (1978). Descriptive analysis of the sensory properties of beverages and gelatins containing sucrose of synthetic sweeteners. *Journal of Food Science,* 43, 47-51.

Lawless, H.T., & Heymann, H. (2010). Sensory evaluation of food. Principles and practices. New York: Chapman & Hall. 587 p.

NNC (National Nutrition Council). (2015). The National Nutrition Council recommends the following actions to improve the iodine intake of the population. https://www.evira.fi/globalassets/vrn/pdf/vrn_jodi_toimenpidesuositus_10_2.2015_english.pdf Accessed 24 March 2018.

Ohlhorst, S. D., Slavin, M., Bhide, J. M., & Bugusu, B. (2012). Use of iodized salt in processed foods in select countries around the world and the role of food processors. *Comprehensive Reviews in Food Science and Food Safety,* 11, 233-284.

Pinkaew, S., & Karrila, T. T. (2015). Key properties of iodine-, iron- and zinc- fortified fish cracker: effects of ambient shelf storage on iodine retention and quality indicators. *International Journal of Food Science and Technology,* 50, 1979–1987.

Puolanne, E., & Peltonen, J. (2013). The effects of high salt and low pH on the water-holding of meat. *Meat Science,* 93, 167-70.

SCF. Scientific Committee on Food. (2003). Report of the Scientific Committee on Food on the Revision of Essential Requirements of Infant Formulae and Follow-on Formulae. 211 pp. https://ec.europa.eu/food/sites/food/files/safety/docs/labelling_nutrition-special_groups_food-children-out199_en.pdf Accessed 24 March 2018.

Waszkowiak, K., & Szymandera-Buszka, K. (2008). The application of wheat fibre and soy isolate impregnated with iodine salts to fortify processed meats. *Meat Science,* 80, 1340-1344.

West, C. E., Merx, R. J. H. M., & de Koning, F. L. H. A. (1995). Effect of iodized salt on the colour and taste of food. New York: United Nations Children’s Fund.

WHO. World Health Organization. (2004). Iodine status worldwide: WHO Global Database on Iodine Deficiency. http://www.who.int/nutrition/publications/micronutrients/iodine_deficiency/9241592001/en/ Accessed 24 March 2018.

WHO. World Health Organization. (2012). WHO Guideline: Sodium intake for adults and children. Report, i-46. http://apps.who.int/iris/bitstream/10665/77985/1/9789241504836_eng.pdf Accessed 24 March 2018.

Winger, R.J., König, J., & House, D.A. (2008). Technological issues associated with iodine fortification of foods. *Trends in Food Science and Technology*, 19, 94-101.

Wirth, F., & Kühne, D. (1991). Manufacture of iodinized meat products. *Fleischwirtschaft,* 71, 1377-1380.

Yebra, M., & Bollaín, M. (2010). A simple indirect automatic method to determine total iodine in milk products by flame atomic absorption spectrometry. *Talanta*, 82, 828-33.

Fig.1. Mean (+ SEM) ratings (n=4*12) of odor, texture, flavor and appearance attributes in a) wheat bread b) bologna sausage c) pickle. The entire rating scale was from -5 to +5, 0 equals reference sample. The mean scores differed max ±0.7 from the reference sample (0 mg/kg). Color codes: ■ 0mg/kg, ■ 25 mg/kg, ■ 50 mg/kg,■ 100 mg/kg. Statistically significant difference from the known reference sample 0 mg/kg: *** $P < 0.001$, * $P < 0.05$.

Table 1. Batch sizes, NaCl contents, added iodine contents as KI and added iodine levels (mg per kg of table salt) in bread, sausage and pickle.

	Batch size (kg)	NaCl (kg)	KI (g)	Iodine (mg/kg)
Wheat bread	200 (dough)	3.030	0.0	0
			0.008	25
			0.016	50
			0.032	100
Bologna sausage	15 (sausage mass)	0.248	0.0	0
			0.099	25
			0.198	50
			0.396	100
Pickled cucumber	40 (pickle juice)	1.560	0.0	0
			0.051	25
			0.102	50
			0.204	100

Table 2. The rated attributes and evaluation instructions for bread, sausage and cucumber.

	Attribute	Instructions	Reference sample for the attribute
Wheat bread			
Odor	Odor intensity		
Texture	Toughness by tearing	Tearing by hands in two parts	
	Moisture in mouth	During 1.-3. bite	
	Smoothness	During 3. bite	
Flavor	Flavor intensity	During 1.-3. bite	
Appearace	Color intensity		
Bologna sausage			
Odor	Odor intensity, a		Snellman™ liver sausage (More than R) (1 day at 21 °C)
Texture	Tenderness, a	Press the knife into the slice	Snellman™, liver sausage (More than R)
	Slipperiness, b	By tongue 1. bite	
	Juiciness, b	3. bite	
	Tenderness in mouth, b	3. bite	
Flavor	Flavor intensity, b	During 1.-3. bites	
Appearace	Color intensity, a		Color map, Tikkurila, Finland. Symphony. Opus II: N564
Pickled cucumbers			
Odor	Vinegary odor	From the pickle juice	10 % (acetic acid) vinegar (More than R)
	Grassy odor	From the pickle juice	
Texture	Crispiness	1. bite (auditory sense)	Fresh cucumber (More than R)
	Chewiness	Softness of flesh, 5. bite	
Flavor	Vinegary taste	1.-3. bite	10 % (acetic acid) vinegar (More than R)
	Sweetness	1.-3. bite	20 % sucrose solution (More than R)
Appearance	Color intensity	From flesh	
	Greenness	From flesh	Color map, Tikkurila, Finland. Symphony. Opus II: N454

a = 8 mm thick slice

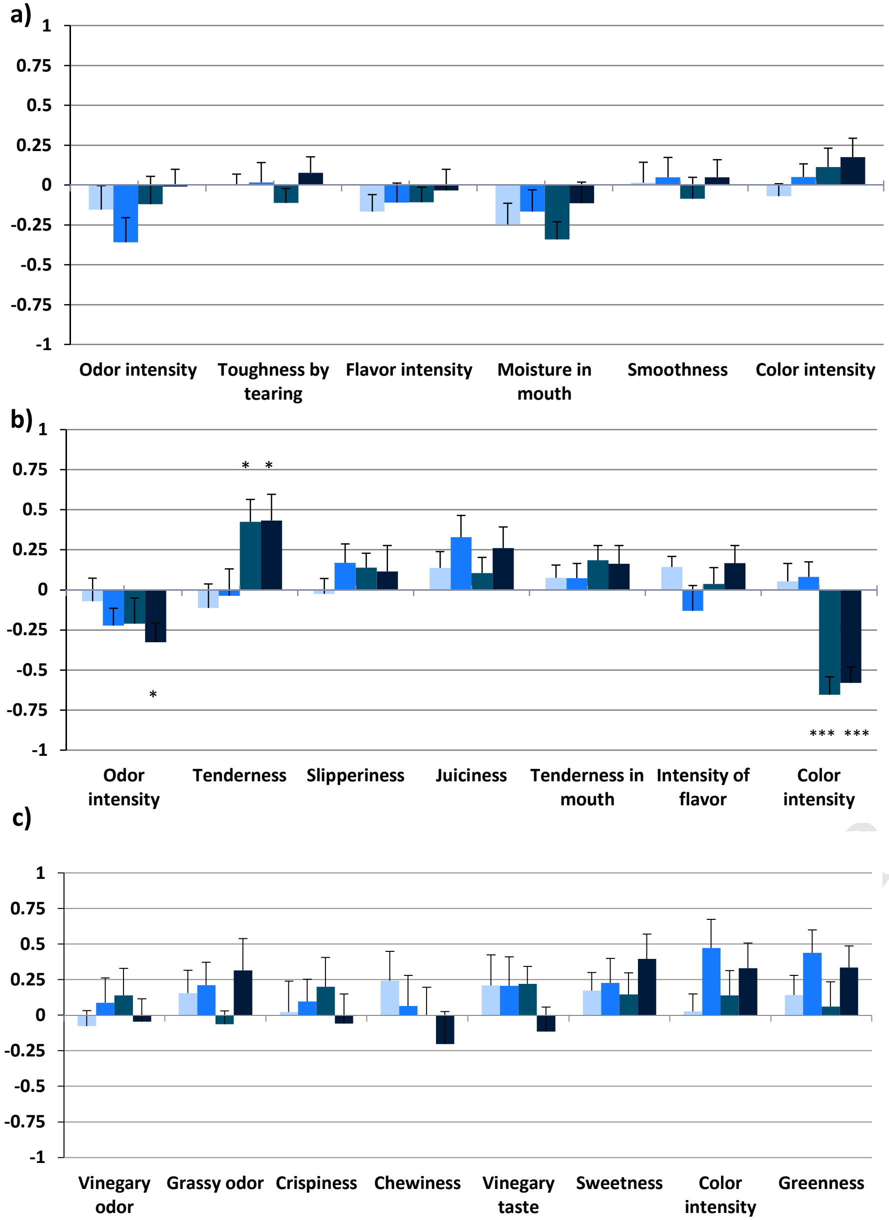
b = 2,5 mm thick slice

Table 3. Chemically analyzed iodine concentrations (mg/kg of table salt) and the resulting iodine retention (%) in each material to which iodine at 25, 50 or 100 mg per kg of table salt was added. Analyzed values (mean, *SD=Standard deviations*) are based on triple replicates.

Added iodine content	**25**			**50**			**100**		
Analyzed iodine content	mg/kg	*SD*	%	mg/kg	*SD*	%	mg/kg	*SD*	%
Bread	20.7	*0.02*	83	40.6	*0.02*	81	75.9	*0.03*	76
Sausage	21.5	*0.06*	86	49.1	*0.03*	98	97.4	*0.04*	97
Cucumber at 5 week	12.4	*0.05*	49	25.3	*0.01*	50	51.3	*0.04*	51
Pickle juice at 5 week	12.5	*0.04*	50	24.5	*0.04*	49	48.0	*0.05*	48
Cucumber at 9 week	12.4	*0.02*	50	23.0	*0.02*	46	46.9	*0.02*	47
Pickle juice at 9 week	11.1	*0.03*	44	20.9	*<0.01*	42	44.5	*0.02*	44

Table 4. Physical properties of sausage at different levels of iodine addition (0, 25, 50, and 100 mg iodine per kg of table salt). Cooking loss and water holding capacity (WHC) means are based on 12 measurements and firmness means are based on 9 measurements. *SD = standard deviation.*

	Cooking loss	Firmness		WHC	
Added iodine mg/kg NaCl	%	N/g	*SD*	g H_2O/100 g meat	*SD*
0	3.3	37	*4*	64	*6*
25	3.9	42	*5*	63	*5*
50	4.2	41	*3*	63	*1*
100	4.5	40	*3*	61	*2*


a)
1
0.75
0.5
0.25
0
-0.25
-0.5
-0.75
-1
Odor intensity
Toughness by tearing
Flavor intensity
Moisture in mouth
Smoothness
Color intensity
b)
* *
*
*** ***
Odor intensity
Tenderness
Slipperiness
Juiciness
Tenderness in mouth
Intensity of flavor
Color intensity
c)
Vinegary odor
Grassy odor
Crispiness
Chewiness
Vinegary taste
Sweetness
Color intensity
Greenness

Mean

Bread	dor intensi	hness by te	avor intensi	sture in mo	moothness	olor intensity
0 mg	-0.15	0.00	-0.17	-0.25	0.01	-0.07
25 mg	-0.36	0.02	-0.11	-0.17	0.05	0.05
50 mg	-0.12	-0.11	-0.11	-0.34	-0.09	0.11
100 mg	-0.01	0.08	-0.03	-0.11	0.05	0.18

Sausage	dor intensi	Tenderness	Slipperiness	Juiciness	Tenderness	ensity of fla	olor intensity
0 mg	-0.07	-0.11	-0.03	0.14	0.08	0.14	0.05
25 mg	-0.22	-0.04	0.17	0.33	0.07	-0.13	0.08
50 mg	-0.21	0.43	0.14	0.10	0.19	0.04	-0.65
100 mg	-0.33	0.43	0.11	0.26	0.16	0.17	-0.58

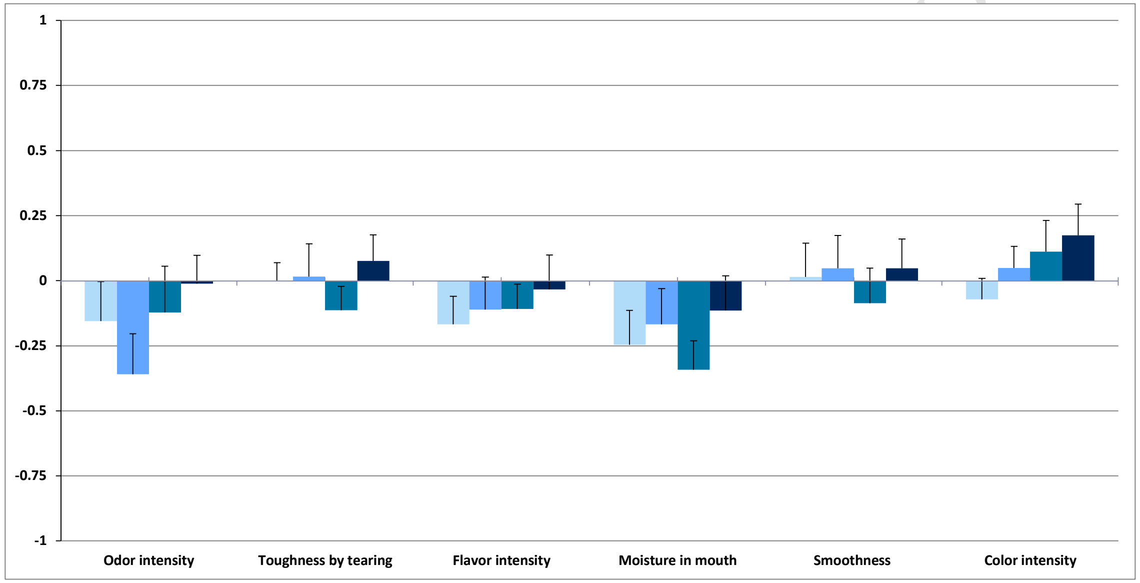
Pickled cu	inegary od	Grassy odor	Crispiness	Chewiness	inegary tast	Sweetness
0 mg	-0.08	0.16	0.02	0.24	0.21	0.17
25 mg	0.09	0.21	0.10	0.07	0.21	0.23
50 mg	0.14	-0.06	0.20	0.00	0.22	0.15
100 mg	-0.04	0.32	-0.06	-0.20	-0.11	0.40

SEM

Bread	dor intensi	hness by te	avor intensi	sture in mo	moothness	olor intensity
0 mg	0.15	0.07	0.11	0.13	0.13	0.08
25 mg	0.15	0.13	0.12	0.14	0.13	0.08
50 mg	0.18	0.09	0.10	0.11	0.13	0.12
100 mg	0.11	0.10	0.13	0.13	0.11	0.12

Sausage	dor intensi	Tenderness	Slipperiness	Juiciness	Tenderness	ensity of fla	olor intensity
0 mg	0.14	0.15	0.10	0.10	0.08	0.06	0.11
25 mg	0.11	0.17	0.12	0.13	0.09	0.16	0.09
50 mg	0.16	0.14	0.09	0.10	0.09	0.10	0.11
100 mg	0.12	0.16	0.16	0.13	0.11	0.11	0.10

Pickled cu	inegary od	Grassy odor	Crispiness	Chewiness	inegary tast	Sweetness
0 mg	0.11	0.16	0.22	0.20	0.21	0.13
25 mg	0.17	0.16	0.15	0.21	0.20	0.17
50 mg	0.19	0.09	0.21	0.20	0.12	0.15
100 mg	0.16	0.22	0.21	0.23	0.17	0.17



- Sensory quality did not change at the recommended iodine level 25 mg/kg of NaCl
- In sausage, 50-100 mg/kg of NaCl was associated with minor sensory changes
- 51-98% iodine retained in products during process and storage
- Iodine content >25mg/kg in table salt could effectively increase iodine intakes