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

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1 LWT – Food Science and Technology

2 **Impact of iodized table salt on the sensory characteristics of bread, sausage and**
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13

14 **Abstract**

15

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

29

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

31

32 1. Introduction

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

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

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

54 Previous studies examining the effect of iodized salt on the sensory properties were
55 conducted a relatively long time ago, and the methods used may not be appropriate or
56 sensitive enough for detecting subtle differences between iodized and non-iodized samples.
57 For example, several studies use hedonic ratings for comparison among iodized and non-
58 iodized samples (Kojima & Brown, 1955; Amr & Jabay, 2004; Chanthilath, Chavasit,
59 Chareonkiatkul, & Judprasong, 2009; Pinkaew & Karrila, 2015). Kuhajek and Fiedelman
60 (1973) found no effect of iodized salt in bread, potato chips and sausage. Similarly, Wirth
61 and Kühne (1991) did not find sensory differences between iodized and non-iodized meat
62 products (iodine added as KIO_3 0.3–0.6 mg/kg of curing salt). On the other hand, Winger
63 et al. (2008) detected small differences in the flavor of tomato juice at high iodine level
64 (200 mg/kg tomato juice) compared to the typical iodine content (25 mg/kg NaCl). Amr
65 and Jabay (2004) observed softening of texture and lowering of color scores in pickled
66 vegetables when 40 mg/kg NaCl as KIO_3 was added. Pinkaew and Karrila (2015) found
67 higher hedonic scores in iodine, iron and zinc fortified fish crackers compared to non-
68 fortified crackers. Iodine was added as KIO_3 (0.26 mg/100 g dough). Also Chanthilath et
69 al. (2009) found no significant differences in fermented fish sauce prepared with non-
70 iodized and iodized salt (iodine as KIO_3 at 30 mg/kg NaCl).

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

78 iodine during boiling but iodine was better absorbed during baking in these products
79 (Comandini et al., 2013).

80 This study examined whether, and to what extent, the addition of iodine to table salt has an
81 impact on the sensory characteristics of selected savory products. The materials were
82 wheat bread, bologna sausage and pickled cucumbers. Bread and sausage were included
83 because they are major sources of NaCl in the Finnish diet (Borodulin et al., 2013). Pickle
84 was selected as the results by Amr and Jabay (2004) suggested changes in color and
85 texture due to iodized salt. Iodine was added to each material 0 mg, 25 mg, 50 mg, and
86 100 mg per kg NaCl. Twenty-five mg per kg NaCl is the level recommended in Finland
87 (NNC, 2015). The 50 and 100 mg were examined as they are typical iodine levels in
88 certain countries. In addition, the iodine content of these foods was studied with chemical
89 analysis. We hypothesized that iodine fortification does not impact the sensory quality of
90 tested products.

91 **2. Materials and methods**

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

95 **2.1. Chemicals**

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

99 The ultrapure water was obtained from a Milli-Q-system (Millipore Corporation, Bedford,
100 MA, USA). Ammonium hydroxide 4.6 g/L was prepared from 182 g/L ammonium

101 hydroxide (BDH, Prolabo, Normatom for trace metal analyses). The iodide stock standard
102 solution (KI in H₂O) was from Romil (Cambridge, GB) and the tellurium stock standard
103 solution (H₆TeO₈ in HNO₃) from Merck (Germany), both 1000 mg/L.

104 For iodine determination 0.1, 0.2, 0.5, 2.5, 5.0, 10, 20 µg/L standard solutions were
105 prepared from the iodine stock solution in 4.6 g/L ammonium. Tellurium was used as
106 internal standard at a concentration of 1 mg/L and was prepared from tellurium stock
107 solution in H₂O. Iodine isotope 127 was used for determination of iodine. The LOQ was
108 0.060-235 mg/kg.

109 **2.2. Salt and brine preparation**

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

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

118 **2.3. Preparation of samples**

119 **2.3.1. Wheat bread**

120 The ingredients of the bread were wheat flour, rye flour, yeast, wheat gluten, vegetable oil,
121 potato flour, rye malt, emulsifier (E471), acidity regulator (E270), ascorbyl palmitate
122 (E304), NaCl and KI. In bread, the dietary fiber content was 3.5 g/100 g. Bread was
123 prepared in a factory scale in 4 batches by a bakery company Vaasan Oy (Helsinki,

124 Finland). For each level of KI, 200 kg of dough was prepared. The bread was baked in the
125 oven (236°C–273°C) for 22 min. The bread loaves were sliced, and the next day they were
126 stored in freezer for 5 days in –18°C. The bread was thawed for three h before the
127 evaluations.

128 **2.3.2. Bologna sausage**

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

138 **2.3.3. Pickle**

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

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

146 15 min). The pickles were stored at room temperature for 38 and 69 days before sensory
147 evaluation.

148 **2.4. Panelists**

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

160 **2.5. Procedure**

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

168 attributes, descriptions, and evaluation techniques in two sessions in which the samples 0
169 mg/kg and 100 mg/kg were compared.

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

178 In bread evaluation, there were three slices of bread of each batch. In sausage evaluation
179 there were four slices of each sausage and in pickle evaluation, five slices of cucumber and
180 20 mL of pickle juice of each batch. The samples were coded with three-digit numbers and
181 their order was randomized for each assessor. Evaluations were conducted in individual
182 booths at room temperature with FIZZ Sensory Evaluation Software, Version 2.45
183 (Biosystemes, Courternon, France). Panelists were instructed to cleanse their palates with
184 tap water between the samples.

185 **2.6. Instrumental measurements**

186 **2.6.1. Determination of iodine concentration**

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

190 The samples were homogenized and microwave digested (bread, sausage, pickle)
191 (Milestone Ethos Plus-2, Chelton, CT, USA) or extracted (pickle juice). Approximately 0.1
192 g of solid samples was weighed into digestion vessel and 1.25 mL of 182 g/L ammonium
193 hydroxide and 10 mL of Milli-Q water was added. The samples were microwave digested
194 as follows: ramping time 5 min at 200°C with power of 1000 W, holding time 15 min at
195 200°C and cooled down time 10 min. Digested sample was transferred into a 50 mL
196 volumetric flask, 500 µL of internal standard was added and the volume filled to 50 mL
197 with Mill-Q water.

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

203 Iodine concentrations were analyzed by inductively coupled plasma mass spectrometer,
204 ICP-MS (Thermo Scientific X-Series 2, Waltham, MA, USA), which is accurate method
205 compared to the previous methods (Winger et al., 2008). The detection levels in ICP-MS
206 method for iodine are lower than the detection levels in other methods (Yebra & Bollain,
207 2010). Finnish Accreditation Service FINAS has accredited the method according to the
208 standard SFS-EN ISO/IEC 17025.

209 **2.6.2. Other measurements**

210 The stability and similarity of the four batches was measured by triplicate pH measurement
211 either during the preparation (dough and sausage mass) or after the storage (pickle juice).
212 Cooking loss and water holding capacity (WHC) (Grau & Hamm, 1957) for sausage were

213 determined by 3 (sausages) x 4 measurements and tenderness (Instron 4466, United
214 Kingdom) by 3 (sausages) x 3 measurements. Brix ($^{\circ}\text{Bx}$) values were determined during
215 the pickle juice preparation with a refractometer.

216 **2.7. Statistical analysis**

217 The sensory ratings were analyzed in relation to the reference sample R with t-test and
218 Bonferroni adjustment in SPSS (SPSS 18.0, PASW Statistics, Chicago, IL, USA).
219 Repeated two-way analysis of variance was conducted to investigate the consistency of
220 ratings (4 iodine levels, 4 replicates [4 x 4]). In pickle, the two storage periods with two
221 replicates were included in the analyses [4 x 2 x 2]. Statistically significant results at $p <$
222 0.05 are reported.

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

225 **3. Results**

226 **3.1. Sensory characteristics**

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

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

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

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

244 **3.2. Iodine concentrations**

245 The retention of iodine varied among the foods (Table 3). In bread, the retention was 76–
246 83%, in sausage 86–98% and in cucumbers the retention was 49–51%. Five weeks after the
247 preparation the iodine content was at the same level in pickle juice and in cucumbers, but
248 at nine weeks, pickle juice appeared to have lost more than the cucumber.

249 **3.3 Other measurements**

250 Cooking loss, firmness and WHC are presented in Table 4. The only significant difference
251 among the batches was in cooking loss [$F(3,24) = 4.1; p = 0.017$], with a significant
252 difference between 0 and 100 mg/kg ($p = 0.013$). Cooking loss was higher in samples with
253 higher iodine content. Tenderness and WHC did not differ between the samples.

254 In the bread dough, pH was 5.5–5.6, and acid value 4.9–5.1. In sausage mass pH was 5.8–
255 6.0 and in cooked sausage it was 6.2–6.3. In pickle juice Brix was 15.9–16.4%. After 5
256 weeks of storage pH in the pickle juice was 3.3 and after 9 weeks it was 3.5–3.6.

257 4. Discussion

258 4.1. Sensory changes

259 The recommended iodine content in table salt, 25 mg/kg, did not result in sensory changes
260 in iodized products compared to the non-iodized products. In bread and pickle, no
261 difference between iodized and non-iodized samples was observed at higher levels (50 or
262 100 mg/kg) either.

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

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

276 The cooking loss from sausage increased with increased iodine level. This is possibly due
277 to weakened WHC (Kauffman et al., 1993) of the sausage. A decrease in WHC was also
278 observed although non-significantly. WHC is known to affect the color and softness of
279 meat (Puolanne & Peltonen, 2013). Sausage mass was prepared in two batches, and the

280 temperature was carefully followed during preparation. Thus, everything was done to
281 minimize the differences between the batches of sausage mass so that the iodine content
282 was the only divider between the four batches. Yet, more research is needed to examine the
283 association between iodine and cooking loss or WHC.

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

292 **4.2. Iodine retention**

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

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

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

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

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

317 **4.3. Reliability of the sensory method**

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

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

332 **5. Conclusion**

333 The commonly used and recommended iodine level 25 mg/kg per kg of table salt did not
334 result in sensory changes in bread, sausage or pickle. The tested products represent a broad
335 range of food products that differ in composition, manufacture and storage time. However,
336 further research is warranted. Other relevant food products high in NaCl, should also be
337 tested for sensory quality and iodine stability. Given the loss of iodine during the
338 manufacturing and the recommendation to decrease the intake of salt (NNC, 2015; WHO,
339 2012), increasing iodine content in table salt should be considered. This would be an
340 effective way to increase iodine intakes at the population level without increasing the
341 consumption of table salt.

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

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351

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442 **Fig.1.** Mean (+ SEM) ratings (n=4*12) of odor, texture, flavor and appearance attributes in
443 a) wheat bread b) bologna sausage c) pickle. The entire rating scale was from -5 to +5, 0
444 equals reference sample. The mean scores differed max ± 0.7 from the reference sample (0
445 mg/kg). Color codes: ■ 0mg/kg, ■ 25 mg/kg, ■ 50 mg/kg, ■ 100 mg/kg. Statistically
446 significant difference from the known reference sample 0 mg/kg: *** P < 0.001, * P <
447 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	
Appearance	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	
Appearance	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

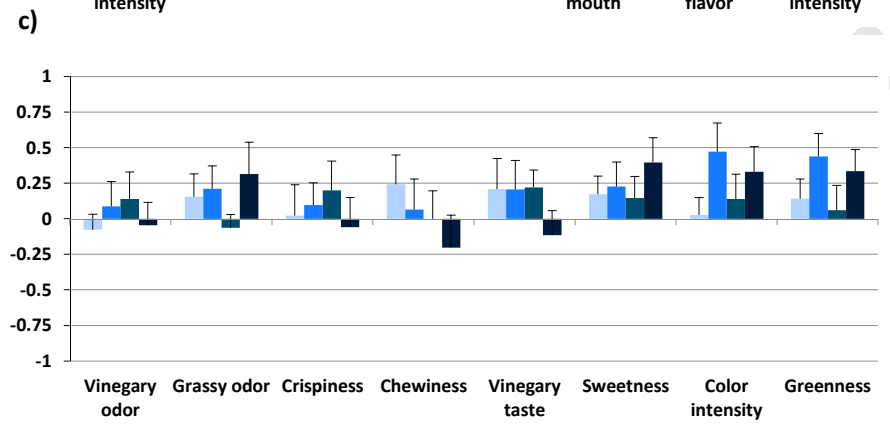
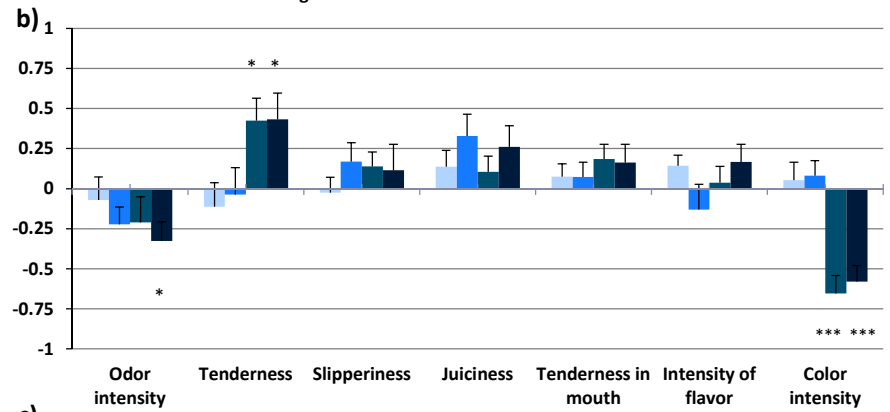
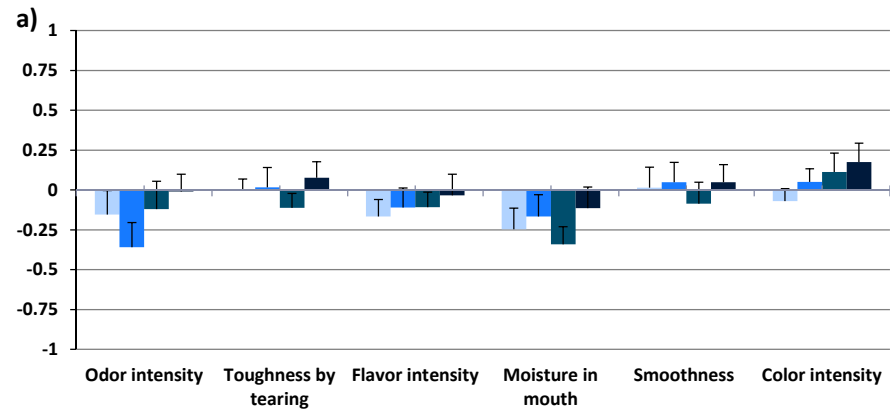
b = 2,5 mm thick slice

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		
	mg/kg	<i>SD</i>	%	mg/kg	<i>SD</i>	%	mg/kg	<i>SD</i>	%
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.

Added iodine mg/kg NaCl	Cooking loss		Firmness		WHC	
	%	N/g	<i>SD</i>	g H ₂ O/100 g meat	<i>SD</i>	
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	



Mean

Bread	odor intensity	toughness by tearing	flavor intensity	moisture in mouth	smoothness	color 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

Sausage	odor intensity	toughness by tearing	flavor intensity	moisture in mouth	smoothness	color intensity
0 mg	-0.07	-0.11	-0.03	0.14	0.08	0.14
25 mg	-0.22	-0.04	0.17	0.33	0.07	-0.13
50 mg	-0.21	0.43	0.14	0.10	0.19	0.04
100 mg	-0.33	0.43	0.11	0.26	0.16	0.17

Pickled cucumber

Pickled cucumber	odor intensity	toughness by tearing	flavor intensity	moisture in mouth	smoothness	color intensity
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

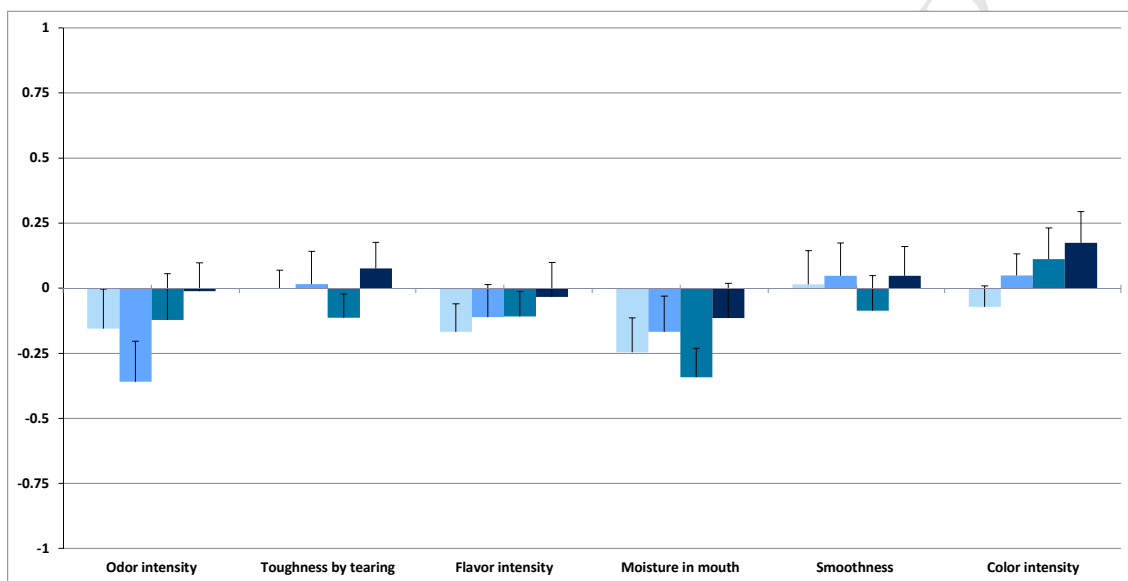
Bread	odor intensity	toughness by tearing	flavor intensity	moisture in mouth	smoothness	color intensity
0 mg	0.15	0.07	0.11	0.13	0.13	0.08
25 mg	0.15	0.13	0.12	0.14	0.13	0.08
50 mg	0.18	0.09	0.10	0.11	0.13	0.12
100 mg	0.11	0.10	0.13	0.13	0.11	0.12

Sausage

Sausage	odor intensity	toughness by tearing	flavor intensity	moisture in mouth	smoothness	color intensity
0 mg	0.14	0.15	0.10	0.10	0.08	0.06
25 mg	0.11	0.17	0.12	0.13	0.09	0.16
50 mg	0.16	0.14	0.09	0.10	0.09	0.10
100 mg	0.12	0.16	0.16	0.13	0.11	0.11

Pickled cucumber

Pickled cucumber	odor intensity	toughness by tearing	flavor intensity	moisture in mouth	smoothness	color intensity
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

ACCEPTED MANUSCRIPT