EFFECT OF IODIZED SALT ON THE COLOUR AND TASTE OF FOOD

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Summary

The aim of the present study was to investigate whether iodine added to salt as potassium iodide or as potassium iodate influences the processing and/or quality (colour, flavour and texture) of foods. Information on the issue has been collected by reviewing the literature back to 1940, and by obtaining information from appropriate persons and institutes. In addition, experiments have been done to investigate the possible influence of iodized salt on the taste and appearance of boiled potatoes and rice.

Reports of studies on a variety of foods such as meat products, cheese, canned vegetables (tomato juice, green beans, whole kernel sweet maize, sauerkraut), bulk sauerkraut, white bread, pickled olives and potato chips, suggest that salt iodized either with potassium iodide or with potassium iodate has no influence on the quality of these foods. Also, our own study on the effect of salt with high levels of iodine (400 mg. I/kg) either from potassium iodide or from potassium iodate on the appearance and taste of boiled potatoes and rice did not show any effect of iodine. There is one report that off-flavours are produced in the presence of cresol which is a constituent of lemon flavouring. However such an isolated report should be seen in the context of the years of experience in Switzerland where iodized salt is used in the food industry. In another study, a mixture of iodine/iodide added at more than 100 times the concentration normally added to tomato juice was shown to affect flavour. Thus a large excess of iodine is required before changes in taste can be detected. Information from different parts of the world has indicated concern that iodized salt may have an effect on the quality of pickled vegetables, but we have not been able to find any hard evidence for such concern.

It can be concluded that neither potassium iodide nor potassium iodate added to salt produce any adverse effects on food quality. The only possible concern is related to salt used for pickling vegetables for which there are no adequate data. Therefore it is recommended that studies should be carried out to determine whether a problem exists with using iodized salt for pickling vegetables.

1. Introduction

UNICEF, WHO and ICCIDD are actively supporting what has become known as “Universal Salt Iodization” to eliminate iodine deficiency in all countries where iodine deficiency disorders are a public health problem. The agencies are advocating that “all salt for human consumption, including salt used in the preparation of processed food, should be iodized to agreed standards with potassium iodate”. However, UNICEF has received information that there are a significant number of countries, mainly middle income countries in the Middle East and in Eastern Europe which have not previously had iodized salt, where the food industry is reluctant to use iodized salt. This is because of fears that the iodine will affect the quality of the foods produced, especially with respect to colour, taste and flavour. In particular, there is a deep concern that the use of iodized salt will result in certain foods (particularly pickles, perhaps starchy products) turning blue after storing, and that it will interfere with the taste of some foods.

The aim of the present study was to investigate whether iodine added to salt as potassium iodide or as potassium iodate influences the processing and/or quality (colour, flavour and texture) of foods. Information on the issue has been collected by reviewing the food science literature back to 1940, and by obtaining information from appropriate persons and institutes. In addition, experiments have been carried out to investigate the possible influence of iodized salt on the quality of boiled potatoes and rice. Suggestions for further studies have also been made.

2. Literature review

2.1 Sources used

The following literature databases have been consulted (on-line or on CD-ROM) in order to find relevant publications:

- Food Science and Technology Abstracts (FSTA)
- Commonwealth Agricultural Bureau database
- Chemical Abstracts
- Biological Abstracts
- Medline
- AGRIOS, FAO
- Leatherhead Food Research Association database, UK
- National Technical Information System (NTIS), USA
- Agricola

Since FSTA only goes back to 1967, the journals "Food Technology" and "Food Research" were screened beyond this date back to 1949 and 1939 respectively. "Current iodine literature" (1954-60), a reference journal from the Chilean Iodine Educational Bureau, London, was also screened manually.

2.2 Chemistry of iodine in foods

The reaction of iodide and iodate in food has not been studied extensively. Studies on the stability of iodide and iodate added to salt suggest that iodate is more stable than iodide. In a humid, acid environment, and in the presence of oxidizing agents, iodide readily oxidizes to iodine, which is volatile. In the presence of reducing agents, iodate is reduced. This is the basis of the use of potassium iodate as a bread improver because it oxidizes the sulphydryl groups of cysteine residues in protein to disulphide bridges.

2.3 Effects of iodine on food quality

Kojima and Brown (1955) studied the effects of iodine from KI and KIO_3 on the quality of canned

tomato juice, canned green beans, canned yellow sweet corn, bottled pickled olives, and canned and bulk sauerkraut. Salt containing 92 mg I/kg either as potassium iodide or as potassium iodate was used for the preparation of the sauerkraut, green beans, and yellow whole kernel corn. The iodine level of the tomato juice was 0.5 and 5 mg/kg, and the brine for the olives contained 154 mg I/kg. After storage for 2-3 months, no effect on colour, flavour, odour, or texture of any of the products was found. Ascorbic acid content of tomato juice and acid formation during sauerkraut fermentation were also not affected.

Following the study of Kojima and Brown (1955), El Wakaeil (1958) evaluated the effect of iodine from potassium iodide added to salt, from solutions of potassium iodide, from an iodine-iodide mixture (containing free iodine), and from an iodophore (containing free and organically bound iodine) on the flavour, colour, texture and pH of canned whole kernel sweet maize, canned tomato juice and canned sauerkraut. In tomato juice and sauerkraut, ascorbic acid (vitamin C) was measured as well, and lactic acid was measured in sauerkraut. Moreover, the effect of sodium thiosulphate, which was then used as a stablizer of potassium iodide in salt, on the above variables as well as on the condition of the cans was studied. The various treatments are summarized in table 1.

With just one exception, no effect of the iodine treatments on flavour, colour and texture of any of the products, on the ascorbic acid content of tomato juice or sauerkraut, or on the fermentation of sauerkraut were observed after up to 12 months of storage. The only exception was an effect on the flavour of tomato juice with the highest concentration of iodine-iodide mixture (200 mg mixture/kg can content). However, the concentration of iodine/iodide reached in the cans was more than 100 times that which would be added normally to tomato juice. Thus a large excess of iodine/iodide is required before changes in taste can be detected. The studies also showed that thiosulphate was responsible for corrosion of the inner walls of the cans (made of tin plate), and for some loss of ascorbic acid. However, thiosulphate is no longer used to stabilize salt.

Table 1. Iodine treatment of canned vegetables and resulting concentrations of iodine-iodide (from the study of El Wakeil, 1958).

Treatments	**Sweet maize**	**Tomato juice**	**Sauerkraut**
Non iodized salt (NIS), concentration, %	1.5 (brine)	1.5	2.5 (total)
Iodized salt[1:] · Salt conc., % · mg. iodide/kg can content	 1.5 (brine) 0.4	 1.5 0.7	 2.5 (total) 1.9
NIS + KI solutions[2:] mg iodide/kg can content	 0.4-152	 0.4-152	 0.4-152
NIS + iodine-iodide mixture: · mg mixture/kg can content · mg iodide/kg can content · mg iodine/kg can content	 -- -- --	 0.5-200 0.06-25.4 0.4-166	 1-100 0.13-12.7 0.8--83
NIS + iodophore (Iosan): · mg Iosan/kg can content · mg iodine/kg can content	 -- --	 0.5-200 0.01-3.5	 1-100 0.02-1.8

[1] Morton Salt Company, max. 112 mg K1/kg.
[2] Together with KI, sodium thisoulphate was added at two concentrations (50 mg/kg and 200 mg/kg can content).

Kuhajek and Fiedelman (1973) evaluated the effects of iodine from potassium iodide, potassium iodate, and calcium iodate added to salt (77 mg I/kg salt) on processing characteristics and quality of white bread, potato chips and frankfurters, and on the iodine stability during processing and storage. No flavour or processing abnormalities were found in this study, and iodine retention was 50-80% throughout processing and storage (10 days in a freezer for bread, 13 weeks at room temperature for potato chips, and approximately 20 weeks in a freezer for frankfurters).

In Switzerland, salt has been iodized since 1920, and iodized salt is used for the production of cheese. In 1926, Koestler and Wegmüller, as cited by Hostettler (1953), investigated the effect of potassium iodide from salt containing 3.8 mg I/kg (the level officially allowed at the time) and 38 mg I/kg on the quality of Emmenthaler cheese. The iodized salt was used to make the brine in which the cheese stayed for two days. The quality of the cheese was evaluated after 4 months, and no influence of iodine at either level was observed. Hostettler (1953) also referred to another study on the influence of iodized salt on the quality of Gruyère cheese. After 77 days and 8 months of ripening, no difference between the iodized and non-iodized cheese could be detected. Furthermore, based on the following theoretical considerations, Hostettler argued that it is unlikely that iodized salt would have any effect on the quality of cheese:

1) If the salt content of cheese is 20 g/kg and the KI content of the salt is equivalent to 3.8 mg I/kg, the level of iodine in Emmenthaler cheese, including iodine derived from milk, would be ca 148 µg I/kg. Such a low concentration is unlikely to have any effect on taste.

2) In Switzerland, iodized salt was used in some Kantons but not in others. If iodied salt was responsible for any changes in cheese quality, such changes would almost certainly have been reported for cheese originating from those Kantons using iodized salt.

Hostettler (1953) concluded that the use of iodized salt in making cheese did not affect the quality of cheese.

The effect of iodized salt on the quality of meat products was investigated in Germany by Wirth and Kühne (1991). Since 1982 table salt in Germany has contained 15-25 mg I/kg from potassium iodate. At the time of the study, it was not permitted to add iodine to nitrite curing salt ("Nitrit Pökelsalz") which is used in the manufacture of most (80-90%) of the meat products produced in the country. Wirth and Kühne compared the effect of incorporating iodine into salt on the processing and quality of meat products manufactured with table salt or with nitrite curing salt. With the products prepared with nitrite curing salt, they also investigated whether reactions between iodate reacted with nitrite, and the changes in the iodine and nitrite levels at different stages of processing and storage.

The following meat products were prepared with iodized or non-iodized table salt: various cooked (pasteurized) sausages such as liver and blood sausage, fresh sausage (e.g. bratwurst), dry cured ham (Rohschinken "Parma-Art"), and fermented sausage. No effect of adding potassium iodate on the processing and sensory characteristics (colour, flavour, odour) of the products have been observed.

The effect of iodizing nitrite curing salt were studied in fresh sausage, cooked cured ham, cooked sausage (liver and blood sausage) and fermented sausage (salami type). The content of these products on a raw basis of salt was 15-28 g/kg, of sodium nitrite was 60-120 mg/kg and of iodine was 300-600 _µg I/kg. No effect of iodate on the sensory characteristics (flavour, odour, colour and texture) and nitrite content was observed. Iodine losses on storage and cooking, where applicable, varied from 25% in brüwurst to 7% in fermented sausage.

According to Wirth and Kühne (1991) there have been reports that the formation of carcinogenic nitrosamines from secondary amines and nitrite is accelerated in the presence of iodide ions. Such an effect could be catalytic or iodine could react in its own right. Wirth and Kühne compared the level of some nitrosamines commonly found in cured meat (N-nitroso-dimethylamine (NPIP), and N-nitroso-pyrrolidine (NPYR)) in iodized and non-iodized fermented sausage. NPIP and NPYR could not be detected in either of the two products, and the NDMA levels were the same in the iodized as in the non-iodized sausage. The authors concluded that addition of iodine to salt had no influence on the formation of nitrosamines in the meat products studied.

The above studies suggest that adverse effects of iodized salt on the quality of foods are highly unlikely. However, negative effects have been reported in a few instances. In a textbook on food science, Joslyn and Timmons (1967) stated that "iodized salt generally should not be used for food processing because of the tendency of potassium iodide to decompose and form free iodine, with possible adverse effects on colour and flavour of many food products". Since this statement was not substantiated by literature references, it must be assumed that it has no basis, apart from a theoretical one.

Off-flavours in processed foods resulting from reactions with iodine present in the food for reasons other than for fortification have been reported in two publications. In a study to examine possible improvement of the efficacy of the heating process in UHT treatment of milk by adding iodate to the milk before heating, a better taste was observed during subsequent storage in milk with 0.1 mM iodate (12.7 mg I/L), but not in milk with 0.05 mM iodate (6.3 mg I/L) (Skudder et al, 1981). This taste was attributed to iodate-induced proteolysis of casein. However, as far as we know the addition of iodate has never been practiced by the dairy industry. Moreover, the lowest concentration of iodate used by Skudder was more than 30 times higher than the content which would be likely to be added to milk by iodized salt. Therefore we assume that this finding has little practical relevance. The second paper by Sevenants and Sanders (1984) from Proctor and Gamble reported an off-flavour in an experimental cake mix prepared with salt containing potassium iodide. Iodocresol was formed by a reaction of cresol present in the lemon flavouring of the cake mix with iodite. Although iodocresol was present in almost undetectable quantities, it affected the product because of its low odour threshold. As a consequence, the authors recommended that "non-iodized salt be used in the product of the cake mix since elimination of cresol was judged to be nearly impossible without drastically affecting product flavour".

3. Information obtained from other sources

3.1 Information supplied by resource persons/institutes

Many people working in universities, research institutes, industry, international organizations or government, and dealing with food science, nutrition, food legislation, IDD, or salt fortification, have been contacted (see Appendix, for list of people contacted). Moreover through the Netherlands delegation to the Codex Committee on Nutrition and Foods for Special Dietary Uses, the issue was placed on the agenda of the meeting of the Committee held 27-31 March, in Bonn, Germany.

At a conference on iodine nutriture in the United States in 1970, the use of iodized salt in processed foods was discussed with food manufacturers and members of the Scientific Research Committee of the National canners had carried out experiments with iodized salt. Experiments with canned vegetables, baby food products, and soup did not show any effect of iodine on the product or on the cans. One canner did report that pork and beans had an objectionable flavour at first, but that it disappeared during extended storage. Another canner, who used iodized salt stabilized with sodium thiosulfate, reported a greater degree of corrosion and sulfide staining in the iodized salt pack of several vegetable products, and that the rate of formation of springers

(swollen cans) was accelerated in tomatoes and in pork-and-beans in tomato sauce. However, the report concludes that sodium thiosulfate used as a stabilizer was the cause of the can corrosion. The interaction between tinplate and thiosulfate was established by El Wakeil (1958). Thiosulfate is no longer used to stabilize salt. At the same conference, Kendall (quoted in Reed and Kendall, 1970) reported that milk solutions with one percent level of added iodized salt, resulted in a metallic or dry sensation in the mouth.

There are consistent rumours that the use of iodized salt for pickling vegetables such as cucumbers, has a negative effect on the quality of the product. According to Brady & Association Inc., Ontario (J.V. Brady, personal communication), iodine has been identified as a cause of cucumber pickles going soft and losing their crispness. In Home and Garden Bulletin No. 92 (US Department of Agriculture, 1970) and in some American cook books (e.g., the Blue Book; Ball Corporation, 1992), advice is given not to use iodized salt when preparing pickling brine because when used "it may darken pickles". From Romania, there are reports that pickling large sweet green and red peppers in vinegar and iodized salt causes them to turn black (D. Alnwick, UNICEF New York, personal communication), and also in Pakistan it is believed that iodized salt cannot be used for pickling vegetables (personal communication from B. Pederson, UNICEF Pakistan). According to the Office of Salt Commissioner, India (S. Sundaresan, personal communication), a paper has been presented to the Nutrition Society of India stating that taste, colour and appearance of pickles change when iodized salt is used for pickling. As yet, we have not seen a copy of this publication.

3.2 **Current research on the effect of iodized salt on food quality**

The following databases containing information on current research projects have been consulted in order to find out whether research is currently being carried out anywhere in the world in the effects of iodine added to salt on food quality:

- AGREP (research in the European Community)
- AGRICOLA
- CRIS (research on agriculture, forestry and human nutrition financed by the US Government)
- ICAR (reserach on agriculture, nutrition, food science and biotechnology in Canada)
- IDRIS (developing countries)

The AGREP database referred to two German studies dealing with iodized salt. The first study, which was carried out by the German Institute of Meat Technology in Kulmbach, and was ordered by the German Army, concerned, amongst other issues, the production of meat products using iodized salt. Results of this study have been published (Wirth and Kühne, 1991) and were discussed above. The second study concerned the extent to which iodized salt is used for artisanal and/or industrial food processing following a change in the German salt legislation of 12/9/89 allowing the use of iodized salt.

4. Present use of iodized salt in industrial food processing

An overview on the legislation for iodized salt in Europe has been made by Bürgi (1993). In Switzerland, iodization of salt is not, but table salt iodized with potassium iodide has been available since 1922. The present level is 20 mg KI/kg (15.6 mg I/kg). Iodized salt may be used for industrial food processing. According to E. Tremp (personal communication), 90% of the table salt sold contains KI, and almost all bakeries and restaurants use iodized salt; 80% of the salt used by the food industry is iodized. A recent study has shown that 90% of the cheese manufacturers use iodized salt (Siber and Schär, 1994).

In the Netherlands, salt has been fortified since 1969. Initially potassium iodide was added to table and cooking salt at 3-8 mg KI/kg and bakers' salt at 23-29 mg KI/kg. However, because of the deterioration in iodine status, possibly associated with lower bread intake, the levels were increased in 1983 to 23-29 mg KI/kg in cooking salt (18-22 mg I/kg) and 55-65 mg KI/kg in baking salt (42-50 mg I/kg). No adverse effects of compulsory use since 12/9/84, practically all bakers still use it voluntarily. It is interesting to note that iodization of table salt has been discontinued.

In Germany, potassium iodate is used to iodize domestic salt on a voluntary basis and the use of iodize salt for industrial food processing has been allowed since 1989, but is not compulsory. As shown above, studies on the use of iodize salt in meat products have been carried out. Wiechen and Hofmann (1994) studied the technical aspects of iodizing cheese, but were not yet satisfied with the result obtained because the iodine was poorly distributed within the cheese. We have been informed that at least one German cheese manufacturer produces iodized cheese but further details ware not available at this stage. Esser and Hötzel (1994) studied the extent of use of iodzied salt and found that of those interviewed, 12% of the food manufacturers and 75% of the mass caterers such as factory canteens, kitchens in hospitals and old peoples homes and youth hostels, used iodized salt.

5 Experiments on the effect of iodine added to table salt on the flavour and appearance of boiled potatoes and rice.

5.1 Introduction

In accordance with the terms of reference, a study was undertaken to investigate the effects of iodized salt on food quality. Because of the limited time available, it was not possible to test foods prepared with iodized foods after storage. Since the food industry has expressed concern that iodine may produce a blue or black colour in starchy products, it was decided to test the influence of iodized salt on the taste and appearance of boiled potatoes and rice which are consumed immediately after preparation.

5.2 **Methods**

Study design: The potatoes and rice were boiled in water with iodized and non-iodized salt, and differences in flavour and appearance between the iodized and non-iodized products were tested by an untrained taste panel using the triangle test. Both salt iodized with potassium iodide and salt iodized with potassium iodate were used. The salt batches were coded so that neither members of the taste panel nor the investigators were aware which batches of potatoes or rice were prepared with iodized or non-iodized salt. Thus the experiments were carried out double masked. The codes were broken after the statistical evaluation of the experimental data was completed.

Salt: In order to make the tests as sensitive as possible, it was decided to carry out studies initially using salt iodized (with either potassium iodide or potassium iodate) at a level four times higher than the maximum level recommended by UNICEF/WHO/ICCIDD (1994). We assumed that if no effect were seen at the higher level, certainly no effect would be seen at the maximum recommended level. The maximum recommended level is that required for salt exported to countries in a warm and humid climate and with an average consumption of 5 g NaC1/person/day, i.e., 100 mg I/kg salt. Thus the initial tests were carried out with salt containing 400 mg I/kg salt. If any effects on food quality were found, it was planned to repeat the tests using salt containing 100 mfg I/kg salt. The actual iodine levels in the potassium iodide fortified salt were 101 and 392 mg I/kg (131 and 510 mg KI/kg) while in the iodate fortified salt these levels were 100 and 375 mg/kg (169 and 630 mg KIO_3/kg).

All salt used for the experiments was prepared by Akzo Nobel Research Laboratory, Hengelo (The Netherlands). The iodized salt was prepared in a high speed mixer. A 2.5 mL aliquot of a solution (260 g KI/L) was added gradually to 5 kg of uniodized salt to obtain the salt containing 131 mg KI/kg while a 10 ml aliquot was added to obtain the 510 mg KI/kg mixture. The high KI salt was dried in a fluidized bed at 20^{o}C but this was not necessary for the low KI salt. The salt with potassium iodate was also prepared in a high speed mixer. Aliquots of 12.5 mL and 50 mL of a solution of KIO_3/kg mixtures respectively. Since the resulting mixtures were wet, they were dried in a fluid bed dryer at 40^{o}C. All salt was delivered in coded, brown glass bottles.

Food preparation: Potatoes of the Bintje variety were peeled and cut in two. Batches of 3.5 kg were boiled in 2.3 L of water with 10.5 g of salt (3 g salt per kg potatoes). The water was heated to boiling in about 10 minutes, and boiling was continued for another 20 minutes with the lid on the pot. Batches (1.0 kg) of Surinam rice were boiled in 1.9 L water with 15 g of salt. The total preparation time was 25 minutes.

Sensory evaluation: The triangle test was used to test for differences in flavour and general appearance between the iodized and non-iodized potatoes and rice. Two samples of one product and one sample of the other product were offered together and subjects were asked to choose the sample which was unlike the other two. Subjects were asked to judge the appearance first, and then to judge the flavour. They were allowed to taste each sample once and then to spit it out.

Between samples, they rinsed their mouths out with tap water. Portions of approximately 30 g were offered at a temperature of 50-55°C on a square aluminum sample tray. Each test was performed by 18 previously untrained subjects with each subject making 6 judgements per test. The subjects were sitting in separate booths with white light supplied by a neon lamp. Statistical analysis was performed on the pooled data.

5.3 **Results and conclusions**

The results of the tests using salt with iodine levels of 400 mg/kg are presented in Table 2. In none of the tests did the number of correct judgments exceed the number required for statistical significance at the 5% level. Therefore, it is concluded that salt containing 400 mfg iodine from potassium iodide or iodate does not effect the flavour and general appearance of boiled potatoes and boiled rice.

Table 2. Number of triangles, correct judgments and critical number of correct judgements (p_0.05) in triangle tests comparing products prepared with uniodized salt and with salt containing potassium iodide (KI) or potassium iodate (KIO_3) at a level of approximately 400 mg I/kg salt.

Food	Iodine source	Trials	Critical Number	Correct judgments	
				Flavour	Appearance
Potatoes	KI	108	44	39	32
Potatoes	KIO_3	107	44	38	38
Rice	KI	105	43	32	41
Rice	KIO_3	108	44	33	27

The questions arises on how much iodine remains with the potatoes and rice. Balauf et al (1988) showed that only a small portion of the iodine added to the cooking water is absorbed by potatoes (0.3-0.5%), rice (± 6%) and macaroni (10-16%). Most of the iodine (70-87%) stays in the cooking water while some (10-25%) is lost with the water which evaporates.

Since no effect of iodine was observed with 400 mfg iodine I/kg salt, the proposed tests with 100 mg I/kg salt were no longer deemed necessary.

6. General conclusion

Studies on the influence of iodized salt on food quality have examined a variety of foods such as meat and dairy products, cheese, canned vegetables (tomato juice, green beans, sauerkraut, whole kernel sweet maize), bulk sauerkraut, white bread, baby foods, soup, pickled olives and potato chips. In none of the studies were adverse effects of iodine reported. There is one study which indicated that off-flavours may occur when iodized salt is used in conjunction with lemon flavouring but this is a minor problem which could be overcome by the highly advanced food industry which would bring such products on to the market. Another study in which iodine/ iodide mixtures were added at more than 100 times that normally used also showed that flavour could be affected. However such high iodine concentrations are unlikely to be achieved in practice. More importantly, there are undocumented reports that iodized salt produces changes in the colour and possibly texture of pickled vegetables. Because of the absence of data, further studies in this area are warranted.

7. Suggestions for further research

As mentioned above, there are undocumented reports that iodized salt produces changes in the colour and possibly texture of pickled vegetables. Further studies are required to investigate whether iodized salt does in fact produce the changes suggested. In addition, the studies carried out as part of this contract should be extended to examine the amount of iodine retained i the foods as consumed. Products such as rice, potatoes and bread, together with pickled vegetables, would be quite suitable for this purpose.

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