REPORT

for

FOOD STANDARDS AUSTRALIA NEW ZEALAND

TECHNOLOGICAL ISSUES
WITH
SALT BRINE ADDITION OF IODINE TO FOODS

by

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1. Background:

Food Standards Australia New Zealand (FSANZ) is considering mandating the use of iodised salt in bread for domestic consumption. One of the methods for achieving this fortification is to dissolve iodised salt in water to form a saturated salt solution, then use this iodised brine as part of the bread formulation. FSANZ wish to assess if there are any significant technical issues associated with this practice and to explore any alternatives that may assist the baking industry overcome perceived obstacles.

2. Terms of Reference

The Consultant will provide technical advice and assistance to FSANZ regarding the following specified tasks:

i) determine the solubility of sodium and potassium iodate in chilled saturated salt solutions;
ii) outline the conditions whereby iodised brining solutions can safely and predictably be used as a food vehicle for iodine fortification, specifically if the salt used is iodised with potassium iodate.
iii) the technical feasibility of using iodised brining solutions as a method of salt addition to bread;
iv) if technological issues are identified, outline possible solutions to resolve these issues.

This will involve:

i). A review of the literature outlining the solubility of iodine, iodides and iodates and any information on the use of iodised brining solutions as a method of iodine addition to food.

ii). Consultations with the salt industry, including the New Zealand salt manufacturer, Dominion Salt Ltd. to obtain any relevant information on the technical feasibility of using iodised brine solutions.

iii). Consultations with the one New Zealand bakery and one Australian bakery using brine as a method of salt addition and advise FSANZ if their current salt addition systems would be suitable for using iodised brine solutions.

iv). If possible, undertake simple analytical procedures to confirm the technical feasibility of using iodised brining solutions.

The technical feasibility of using iodised brining solutions as a method of salt addition to bread including:

- The solubilities of the different forms of iodised salt.
- Current salt iodisation practices in the Australian and New Zealand salt industry.
- Current baking practices for using brine solutions as a method of salt addition.
- The probable iodine dispersal in differing iodised salt concentrations under different conditions, such as temperature, agitation and time.
- The safety and predictably of using iodised brine solutions as a method of salt addition in bread making.
- Outline possible solutions if technological issues are identified with using iodised brining solutions as a method of salt addition to bread.

3. Iodisation of industrial salt in Australia and New Zealand

3.1. Current Regulations

The Australia and New Zealand Food Standards Code defines salt and iodised salt in particular under Standard 2.10.2 “Salt and Salt Products”. Specifically:

iodised salt means a mixture of salt and -

(a) potassium iodide or potassium iodate; or
(b) sodium iodide or sodium iodate.

salt means the crystalline product consisting predominantly of sodium chloride, that is obtained from the sea, underground rock salt deposits or from natural brine.

Composition of salt:

(1) Salt must contain no less than 970 g/kg sodium chloride on a dry matter basis, exclusive of permitted food additives.

(2) Salt must contain no more than –

(a) 0.5 mg/kg of arsenic; and
(b) 2 mg/kg of lead; and
(c) 0.5 mg/kg cadmium; and
(d) 0.1 mg/kg of mercury.

Composition of iodised salt:

Iodised salt must contain potassium iodide or iodate, or sodium iodide or iodate equivalent to –

(a) no less than 25 mg/kg of iodine; and
(b) no more than 65 mg/kg of iodine.

3.2. Production of iodised salt in Australia and New Zealand

From discussions with Dominion Salt Limited (New Zealand) and Cheetham Salt Limited (Australia), it appears the production of iodised salt for industrial use will specifically involve the dry mixing of potassium iodate into standard industrial salt. This section specifically focuses upon this method of preparation and its potential use by the food industry.

The process may be done differently by different salt mills. Generally, potassium iodate would be premixed in a small quantity of salt and then metered into a mixing line with a large batch of salt. Cheetham Salt Limited mills the commercially available potassium iodate further to a fine powder before adding to the salt whereas other producers do not necessarily do so.

In essence, therefore, potassium iodate is distributed around the bulk salt by dry mixing and as such exists as discrete particles amongst the various grains of salt. The quantity of iodate that would be detected in any sample of salt will depend heavily upon the sample size. The bigger the sample, the closer the concentration to the mean concentration set by the salt producers.

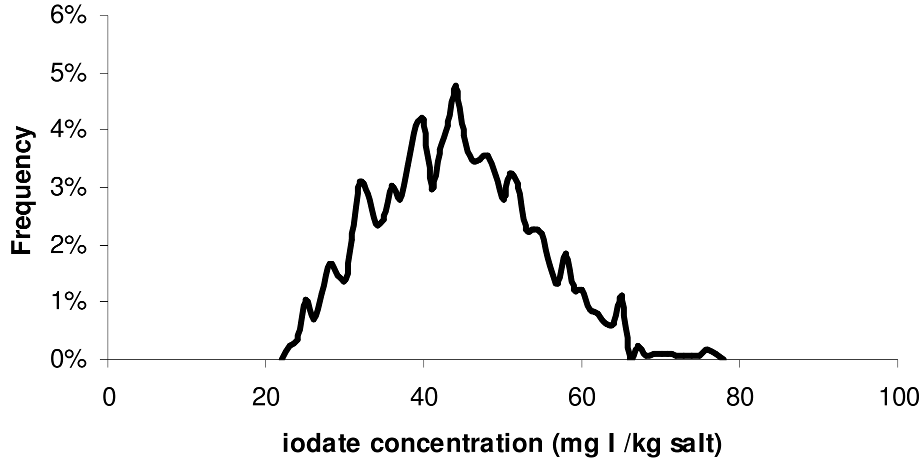
Cheetham Salt Limited provided an excellent summary of the quality control specifications they have achieved for iodised salt over the last 2 years (Figure 1).

From 1719 quality control sample measurements taken since early 2006, the production process resulted in iodine levels of mean of 44mg and one standard deviation of 9.9mg per kg salt. Sample size is 50 grams. From a statistical point of view, three standard deviations around a mean for a normal distribution curve will account for 99.7% of all samples tested. This means any single 50g sample of this iodised salt will have an actual measured iodine content between 14.3 and 73.7 mg I/kg salt. However, this result reflects the small sample sizes taken for analysis. The larger the sample of iodised salt, the greater the likelihood the measured iodine content will be closer to the mean value.

For example, if a 500 g sample of iodised salt had been used, the mean value would still be 44 mg iodine per kg salt, but the standard deviation would be [9.9 X 1 / (√(500/50))], which is 3.13 mg iodine per kg salt. Thus for 500 g samples of iodised salt, the range of iodine values (3 standard deviations) would be from 34.6 to 53.4 mg I/kg salt.

Using dry blending of iodate into salt will result in the sort of distribution shown in Figure 1. It is possible that salt producers who do not mill their potassium iodate before addition to the salt will have a wider distribution than those shown for Cheetham Salt Limited.

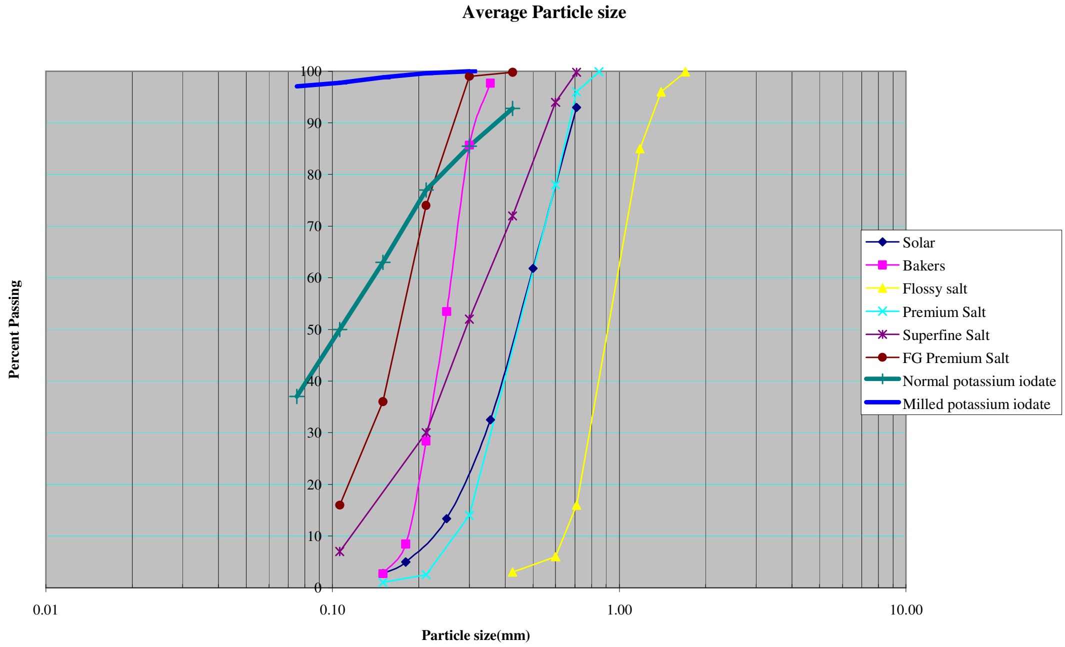
Figure 1: Iodine concentration profile in iodised salt



Data from Cheetham Salt Limited, Australia. Uses powdered (milled) potassium iodate dry mixed into sodium chloride. Potassium iodate contains 59.3% iodine. Mean iodine content 44 mg I/kg salt (standard deviation 9.90 mg I/kg salt) or 74.2 mg potassium iodate/kg salt.

From a pragmatic perspective, iodate is distributed throughout the salt in discrete particles. The size distribution of salt and iodate are presented in Figure 2.

Figure 2: Particle size distribution of industrial salts and potassium iodate in Australia and New Zealand.



Salt data from Dominion Salt Limited, New Zealand (Solar, Bakers) and Cheetham Salt Limited, Australia. Iodate data from Cheetham Salt Limited, Australia.

These data show a wide range of particle sizes for industrial salt. The potassium iodate used has a smaller particle size than the industrial salts in New Zealand. The milled potassium iodate used at Cheetham Salt Limited is a very fine powder and has a narrow particle size distribution. It is reasonable to expect both forms of iodate to distribute well throughout the salt, but the milled iodate potentially will have a better and more uniform distribution (smaller standard deviation from sampling). This does not pose any significant technical difficulties for the use of iodised salt in the food industry.

3.3. *Stability and solubility of iodine compounds.*

There are four iodine-containing chemicals permitted for use in foods in Australia and New Zealand: sodium iodate, potassium iodate, sodium iodide and potassium iodide.

The iodides are not recommended for addition to salt because they are very sensitive to oxidation, including from oxygen in the air. Their stability in salt is poor and their stability in food systems containing oxidising agents is considered to be worse. The global view from major salt companies and the literature supports the exclusion of potassium and sodium iodide from salt because of their instability and very short shelf life in the presence of minute amounts of moisture.

Thus the preferred compounds to be added to salt are sodium and potassium iodates. Of those two forms, potassium iodate is the one which will be used by the major salt companies supplying the food industry in Australia and New Zealand.

Iodates themselves are unstable and are readily destroyed at room temperature in salt solutions containing Vitamin C and sulphites (Chavasit et al., 2002). The standard analytical test for iodate in foods is to add an excess of iodide, which results in the rapid, quantitative conversion of iodate to iodine. The iodine is then measured by titration with thiosulphate to quantify the original iodate. Thus care must be exercised when solubilising iodates into solution prior to their use in food systems. Brines should not contain reducing agents of any sort.

The Food Standards Code requires concentrations of potassium iodate added to salt to be 25 to 65 milligrams of ***iodine*** per kg salt. There is 59.3% iodine in potassium iodate. The upper limit – namely 65 mg I/kg salt – represents 109.6 mg potassium iodate/kg salt (or approximately 110 mg potassium iodate per kg salt).

The solubility of salt and various iodine compounds in pure water is provided in Table 1. The solubility of salt (sodium chloride) is relatively unaffected by temperature from 0 to 30°C. Potassium and sodium iodides are extremely soluble in water, but are not the preferred form for use in salt, or food, because of their lability. The solubilities of potassium and sodium iodates are affected by temperature.

Table 1: Solubility of sodium chloride and iodine compounds in pure water

Compound	0°C	10°C	20°C	30°C
sodium chloride	35.7	35.8	35.9	36.1
potassium iodate	4.60	6.27	8.08	10.30
sodium iodate	2.48	4.59	8.08	10.7
potassium iodide	128	136	144	153
sodium iodide	159	167	178	191

Concentrations are expressed in terms of grams of compound per 100 g water.
Source: Speight (2005).

Based on these data, 46,000 mg of potassium iodate will dissolve in one litre of water at 0ºC. As there is only 110 mg potassium iodate per kg salt and salt would normally be added to food at about 0.5 to 3% concentrations, it is clear that potassium iodate would easily dissolve in the amount of water used to make brine solutions, even for saturated salt solutions.

However, as potassium and sodium iodates are sparingly soluble, their solubility is expected to be affected by saturated salt solutions. There are no data available on the solubility of iodates in saturated salt solution. Experimental work conducted at Massey University shows there is a significant effect of a saturated salt solution on the solubility of the iodates (see Table 2).

Two matters are clear from Table 2. Firstly, these is a significant reduction in the solubility of the iodate salts in saturated salt solutions. Secondly, the way which iodate is solubilised may have a significant effect on solubility as well.

However, from a pragmatic perspective, while there is a major reduction in the solubility of potassium (and sodium) iodate in saturated salt solutions, the solubility is still considerably higher than the maximum permitted concentration added to salt (110 mg potassium iodate per kg salt). At this additive level there would be 2.86 mg potassium iodate per 26 grams of salt. The worst case scenario for potassium iodate at 0°C is a solubility of 740 mg per 100 ml saturated solution. The maximum permitted amount of potassium iodate would therefore be totally dissolved in the saturated solution.

There is no anticipated technical problem with dissolving potassium iodate in saturated salt solutions at the level added to salt. Potassium and sodium iodate dissolve reasonably quickly in water and provided the salt is completely dissolved prior to use, all iodate will be solubilised.

Table 2: Experimentally assessed solubility of saturated salt and iodate solutions

Compound	**dissolved in**	**0°C**	**10°C**	**20°C**
sodium chloride	water	26.35±0.05	26.60±0.08	26.51±0.04
potassium iodate	**water**	**5.08±0.02**	**6.86±0.03**	**8.30±0.01**
sodium iodate	water	2.80±0.02	4.69±0.01	8.21±0.01
potassium iodate[a]	**saturated salt**	**1.07±0.01**	**1.65±0.01**	**1.96±0.01**
sodium iodate	saturated salt	0.75±0.02	1.32±0.02	2.24±0.01
potassium iodate[b]	**saturated salt**	**0.74±0.02**	**1.17±0.01**	**2.46±0.01**
sodium iodate	saturated salt	0.58±0.01	1.04±0.01	1.89±0.01

These results are consistent with those found in the literature. Note that the values in Table 2 are presented as grams per 100 ml of solution and are different to the units in Table 1.

Data are means and standard deviations of 3 replicate samples.

a. These iodate compounds were added to saturated sodium chloride solutions which had been equilibrated at the defined temperatures.
b. These iodate compounds were first saturated at the defined temperature in water, and then sodium chloride was added to its saturation point. Note that in this situation, potassium and sodium iodate precipitated from the solution as the concentration of sodium chloride increased.

In all experiments, saturated solutions were made and stirred at the temperatures indicated for at least 4 hours before iodate measurements were made. Iodate was measured following quantitative conversion to iodine, then titration of the iodine with sodium thiosulphate using starch as an indicator.

4. Use of iodised salt for bread making in Australia and New Zealand

There appear to be three methods proposed for adding iodised salt to bread: adding the salt directly as an ingredient; dissolving the salt in water and adding as a “brew” system, and; using a saturated brine solution.

4.1. Directly adding dry salt

The addition of iodised salt as a solid, dry ingredient is straight forward and the iodine availability will be as good as the distribution of potassium iodate throughout the salt. There does not seem to be a technical issue associated with this option.

4.2. Dilute salt solutions

In this system, a bread manufacturer may make a batch of water, salt and other additives which is sufficient for an entire day’s bread production. Provided the salt solution is significantly less than saturation (ie less than about 36 g salt/100 g water) and the salt is completely dissolved before use, there are no technical issues associated with this as a physical process. However, the addition of bread improvers into this solution, in addition to the iodate, might create chemical reactions which could destroy the iodate. The only way to assess this is through experimentation, as there are no known publications which provide any justification for this conclusion.

4.3. Saturated brine solutions

This assumes that a cold, saturated brine solution (35-36 g salt per 100 g water) is prepared and used continuously over a prolonged period. This may be a commercial prerogative for modern, computerised and completely enclosed production systems which are known to exist. This saturated brine solution would be used for all the production in the factory – bread and all other baked goods. The computer would call the appropriate amount of saturated salt solution into the mixer on a batch basis. In this system, provided the solution was only salt and all the salt added to the tank was completely dissolved, there is unlikely to be any chemical reaction with other ingredients or reducing agents and the salt and iodate would be correctly dosed.

However, if procedures used actually involve adding more salt to the tank than will be fully dissolved, then there will be a problem with the dosing of iodate. In particular, all the iodate in the entire amount of salt added would dissolve in the saturated salt solution meaning the actual amount present in solution would be highly variable.

4.3.1 Further considerations for companies using saturated brine technologies

This operating system is sophisticated, highly mechanised, computer-controlled and completely closed. If a company used this system to manufacture all their goods, there is no straight forward manner to add iodate specifically to domestic bread alone through the continuous process. While iodised salt could be used in the brine tank, there is no way to exclude iodate from products. This matter could be particularly important if such a bakery had a major export trade to Japan, for example which prohibits the import of any food containing added iodine. Trace amounts of iodine will result in immediate rejection of the manufactured goods in that market. Thus there may be a pragmatic issue of addition of iodate to domestic bread products using this setup.

In this instance, potassium iodate might be able to be added directly as a special ingredient. However, assuming the bakery makes 100 kg batches of dough (typical of such a setup) and if the salt content of the dough (before baking) was 1% (an hypothetical value but appropriate for bread) this equates to 1 kg salt at 110 mg potassium iodate per kg salt – or the company would need to add 110 mg potassium iodate per 100 kg batch of dough. This is a very small amount and it is unlikely a food manufacturer could routinely add this micro-amount of iodate in a reliable and consistent manner. The most appropriate method would be to make a concentrated potassium iodate solution (say 1.1 g per litre) and add 100 ml of that solution to a batch of dough. At this current point in time, there is no permission in the Code to allow the direct addition of iodine to bread.

It is possible, with further investment, that modifications to the operations and / or equipment might allow the selective addition of iodised salt to domestic bread. These changes may involve batch addition of iodised salt and water, separately, but directly to the mixer. This is a significant alteration in operations and would likely require additional staff and separate rooms to prepare salt to ensure no accidental cross-contamination. Alternatively, additional expenditure to install new equipment and redesign the process line may be possible.

5. Conclusions

Potassium iodate is the chemical most likely to be added to salt by the major salt suppliers to the food industry in Australia and New Zealand. This can be reliably achieved and would provide the industry with a suitably consistent and controlled way to add iodine to processed foods.

In Australia and New Zealand, the maximum permitted concentration of iodine is 65 mg per kg salt which equates to 109.6 mg of potassium iodate per kg salt. At this level, there is no difficulty in dissolving the potassium iodate completely in water, up to the saturation point of the salt itself (roughly 36 g sodium chloride per 100 g water). It should be noted, however, if the salt does not dissolve completely, that it is likely that all the potassium iodate would readily dissolve and the resulting solution will have an excessive level of iodine. If this solution is used in some batches and more water or salt is added to the brine, the concentration of potassium iodate in the product will vary over the day's production. It is important, therefore, to ensure that the addition of iodised salt to food requires:

1. the dry addition of iodised salt; or

2. the use of a brine solution where the salt is totally dissolved before being used in the food production operation.

The addition of iodised salt as a dry ingredient directly to a batch of product (dough in this instance) is readily achievable and has no perceived technological issues.

The use of brine solutions is technically feasible and is used in some commercial manufacturing operations in both Australia and New Zealand. Provided the salt is completely dissolved to form either a saturated or more dilute solution, the addition of this brine to dough should be relatively straight forward, and iodine addition can be expected to be at least as effective as the dry salt addition.

However, if there are other food additives incorporated into the brine (eg reducing agents), there may be some reaction with the iodate and this would result in loss of iodate from the solution. As a result, it is critical that reducing agents are not added to the brine, but rather incorporated into the dough through alternative means. Experimental evidence assuring iodine levels are unaffected should be obtained if any additives are incorporated into the brine with the iodised salt.

There is at least one sophisticated modern bakery which has an integrated, closed system using a saturated brine solution for their processing operation. This operation has not been designed to allow routine addition of micro-quantities of food ingredients or additives. The system cannot utilise two separate saturated salt solutions, meaning whatever salt is used (iodised or not) will determine the composition of all their product lines. Some product lines are likely to include export baked goods which must not contain added iodine. It is not possible, with the current set-up, to adjust their process line to manufacture both export products without iodine and domestic bread with iodine added. This company (and any other like it) will need to introduce new methods, spend additional capital plus incorporate new quality control checking to achieve a mandatory addition to domestic bread dough.

In general, while there appears to be no technological issue associated with the addition of iodised salt to bread for the majority of the industry, there may be some companies using brine systems who will be required to invest in modifying their existing facilities to include iodised salt specially in domestic bread.

6. References

Chavasit, V., Malaivongse, P., and Judprasong, K. (2002). Study on stability of iodine in iodated salt by use of different cooking model conditions. J. Food Composition and Analysis 15: 265-276.

Speight, J.G. (2005). Lange's Handbook of Chemistry. 16th Edition. McGraw-Hill, USA.