

**CONSIDERATION OF MANDATORY
FORTIFICATION WITH IODINE
FOR AUSTRALIA AND NEW ZEALAND**

FOOD TECHNOLOGY REPORT

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1 Introduction

Food Standards Australia New Zealand is considering mandatory fortification of the food supply in Australia and New Zealand with iodine.

Generally, the addition of iodine to foods is technologically feasible. However, in some instances the addition of iodine can lead to quality changes in food products such as appearance, taste, odour, texture and shelf life. These changes will depend on the chemical form of iodine used as a fortificant, the chemistry of the food that is being fortified, the food processes involved in manufacture and possible processing interactions that could occur during distribution and storage.

Many foods have been fortified with iodine and the potassium salts of iodine compounds have been used as the preferred form.

2 Forms of Iodine

Iodine is normally introduced, or supplemented, as the iodide or iodate of potassium, calcium or sodium. The following table lists different chemical forms of iodine along with their important physical properties.

Table 1: Physical Properties of Iodine and its Compounds

Name	Chemical Formula	% Iodine	Solubility in water (g/L)				
			0°C	20°C	30°C	40°C	60°C
Iodine	I ₂	100	-	-	0.3	0.4	0.6
Calcium iodide	CaI ₂	86.5	646	676	690	708	740
Calcium iodate	Ca(IO ₃) ₂ ·6H ₂ O	65.0	-	1.0	4.2	6.1	13.6
Potassium iodide	KI	76.5	1280	1440	1520	1600	1760
Potassium iodate	KIO ₃	59.5	47.3	81.3	117	128	185
Sodium iodide	NaI·2H ₂ O	85.0	1590	1790	1900	2050	2570
Sodium iodate	NaIO ₃	64.0	-	25.0	90.0	150	210

Adapted from Mannar and Dunn (1995)

2.1 Potassium Iodide

Potassium iodide (KI) is highly soluble in water. In most impure salts potassium iodide is not very stable due to both oxidation, and migration and then subsequent evaporation. Oxidation to iodine occurs if storage conditions are either humid or highly aerated, involve exposure to sunlight or heat, the presence of impurities or moisture in the salt or an acidic environment. Loss of iodine is decreased when salt that is iodised with potassium iodide is very pure (refined) (>99.5%) and dry (<0.1% moisture), as well as with the addition of stabilisers and drying agents (Mannar and Dunn, 1995).

Potassium iodide is cheaper than potassium iodate and the percentage of iodine by weight is also greater. However, overall cost may be higher if used in an impure salt due to its instability in comparison to potassium iodate. Due to its solubility in water, potassium iodide is more readily dispersed by addition as a liquid to the salt slurry before drying.

2.2 Potassium Iodate

Potassium iodate (KIO_3) is more stable in unrefined salt than the iodide, removing the need for extra stabilisers or carrier agents. It is also more stable in unfavourable atmospheric conditions such as in high humidity. This is the form that is currently used in Australia and New Zealand for the iodisation of salt. Although potassium iodate is less soluble in water than potassium iodide, losses are greatly reduced as it is less likely to migrate from packaging, and solutions of sufficient concentrations up to 4%, are still easily prepared Mannar and Dunn, 1995). Iodates can be added to dried salt in powder form.

Potassium iodate has been evaluated by the Joint Food and Agriculture/World Health Organization Expert Committee on Food Additives (JECFA) as a flour treatment agent. Potassium iodate has been assigned the International Numbering System number (INS) 917 and is specified by JECFA.

2.3 Sodium Iodide and Iodate

Sodium iodide (NaI) is even more soluble than potassium iodide (KI). Similarly the sodium salt of iodate is more soluble than the potassium salt. The sodium salts provide higher percentages of iodine compared to the potassium salts but they are also more reactive and therefore less stable than the potassium salts. Sodium salts of iodine are suitable alternatives to the potassium salts.

2.4 Calcium Iodide and Iodate

In comparison to the potassium and sodium compounds, calcium is much less soluble in water, limiting its applicability. Calcium iodate ($\text{Ca}(\text{IO}_3)_2$) is not used to a great extent for this reason, even though it is also stable in impure salts (Mannar and Dunn, 1995). There have also been some reports of off-flavours when calcium salts are used, due to the calcium ions, (Kuhajek and Fiedelman 1973 cited in FAO, 1996).

2.5 Permitted Forms

Voluntary addition of iodine is currently permitted to salt at a concentration range from 25-65 mg /kg in Australia and New Zealand in Standard 2.10.2 – Salt and Salt Products. The permitted forms listed are sodium and potassium salts of iodide and iodate. Iodised salt and foods produced with iodised salt are required to be appropriately labelled.

Both iodide and iodate are relatively strong oxidizing agents in comparison to other inorganic anions in foods (Fennema, 1985). There has been concern from industry that the fortification of food with iodine may therefore lead to technical challenges associated with food processing and quality changes in food products in terms of appearance, taste, odour, texture and shelf life. However, the amount of additional iodine in food resulting from most fortification scenarios is typically small.

3 Potential Food Vehicles

3.1 Sugar

The use of sugar as a carrier for iodine was studied in Sudan for use in endemic iodine deficiency cases. Sugar was assessed as a suitable carrier to increase iodine levels across the population. Improvements including decreases in the rates of goitre, and increases in the level of urinary iodine and thyroid hormone values were recorded with no side effects noted.

The iodised sugar was produced by adding iodine to a sugar solution before it was crystallised in an evapocrystalliser, or it was sprayed over the cured sugar before being dried (Eltom *et al.*, 1995).

3.2 Oil

Lipiodol is the brand name of iodised poppyseed oil. It is the major alternative to iodised salt for correcting endemic iodine deficiency used in some developing countries, such as Algeria. Single oral doses containing 240 mg of iodine will cover a child for 6 months (Benmiloud, *et al.*, 1994). Lipiodol has also been given during pregnancy to normalise thyroid function of both mothers and newborn babies, increase placental weight and reduce the frequency of iodine deficiency disorders in Algeria (Chaouki and Benmiloud, 1994 cited in Delange and Hetzel, 2004).

Lipiodol has also been used as a single iodised oil injection (4 mL) in treating iodine deficiency in Papua New Guinea, and was found by Buttfield and Hetzel (1967) to remain effective for four and a half years. Iodised oil has a great advantage in that it does not require refrigeration (Delange and Hetzel, 2004).

Untoro *et al* (1998, p 753) reported that iodised peanut oil, which has been used in Indonesia since 1993, has higher iodine retention than Lipiodol due to its higher proportion of monounsaturated fatty acids.

The applications involving iodisation of oils are as supplements rather than as iodisation of oils for use in cooking.

3.3 Liquid Milk

The use of iodophors as equipment sanitisers in the dairy industry contributed to the iodine intake of the human population in the past (Joerin and Bowering, 1972; Sutcliffe, 1990 cited in Grace and Waghorn, 2004). The decline in use of iodophors subsequently lowered the iodine intake of the population (Thomson, *et al.*, 1997). Adding iodine to milk as a direct fortificant poses some technological problems as milk is a single ingredient food with no mixing step. The effects of different pasteurisation times, heat treatments and storage conditions may also affect iodine levels in different liquid milk products.

Two on-farm methods of increasing iodine levels in milk are mentioned in the literature. The first involved supplementing feed with iodine and the second used an intramuscular injection of iodised oil.

Kaufmann and Rambeck (1997) reported that the concentration of iodine in milk increases with the increasing level of supplementation in the feed of the animal, as iodine is readily transported across membranes of the digestive tract. Supplementation with iodine at up to 100 mg produced iodine levels in the milk of 493 +/- 125.3 µg/L and did not change the fundamental sensory properties of the milk.

To avoid large variations in iodine concentrations in milk due to seasonal and regional factors, as well as providing a practical alternative to pasture-fed supplementation, it has been suggested that a long-acting injectable supplement of iodised oil is a viable option (Knowles *et al.*, 2004). Treatment schemes for this method have been outlined by Grace and Waghorn (2004), with a general finding being that multiple injections could maintain iodine concentrations of 60 µg/L for the entire lactation.

Problems associated with increasing iodine levels in milk via supplementation of the animal can include increased costs to the primary producer and the inability to maintain consistent levels between farms. Batches are almost always blended in transport and at the dairy processing plant. The possible variation in iodine levels in different milk products such as whole milk, 2% fat and skim milk may also warrant investigation as iodine salts will dissolve in the aqueous phase but are more likely to promote organoleptic changes in the milk fat.

Milk consumption is not uniform across the population. With some consumers, particularly lactose intolerant individuals, using alternatives to cow's milk, tandem fortification of these products may also need to be considered.

3.4 Rice and Other Grains

Rice has been fortified with other vitamins and minerals such as iron, calcium and B vitamins. Fortification of rice can be problematic as it is most commonly consumed as the whole grain and is often rinsed prior to cooking (FAO, 1996).

Techniques used for addition of nutrients to milled rice products include application of an enrichment 'premix' of vitamins and minerals directly after milling of parboiled rice to aid in adherence of the powder to the grain due to the residual heat and moisture from milling. A major drawback of this method is that subsequent washing prior to cooking leads to losses of 20-100% of nutrients (Hoffpauer, 1992; Hoffpauer and Wright, 1994 cited in FAO, 1996).

There is another method mentioned in literature that involved milled rice soaked in the water-soluble vitamins and an acidic medium. The subsequent cross linking of starch granules lead to initial significant vitamin loss, but increased retention of vitamins during rinsing and cooking (Joseph *et al.*, 1990 cited in FAO, 1996).

Techniques for enrichment of cereals can involve application of powdered premixes or spraying of nutrient solutions followed by drying to the milled grains followed by a coating of a water-insoluble substance as a sealant (Cort *et al.*, 1976; Hoffpauer, 1992 cited in FAO 1996). These methods for fortification have been used in the USA for nutrients including thiamine, riboflavin, niacin, iron, vitamin D and calcium. This sort of application method has been found to be much more stable to rinsing, with vitamin losses of 0.2-1.1%. Problems have been encountered due to discolouration of the grain due to the presence of some vitamins including riboflavin.

Fortification of whole grain cereals with iodine may be problematic as iodine may be present in foods as iodide or iodate, and these are both relatively strong oxidizing agents. As has been found with soluble iron compounds they may reduce shelf life by promoting oxidation of the lipid component of the grain (FAO, 1996). Iodine fortification may also be problematic due to discolouration of fairly neutral-coloured grains such as white rice.

3.5 Salt

Almost all the research, to date, to increase the iodine content of the food supply has involved the use of iodised salt in processed foods rather than direct addition of iodine in its various forms to food. Mannar (1988) as cited in FAO (1996) describes four technologies used in the addition of iodine to salt – Spray mixing, dry mixing, drip feed addition and submersion.

Most commonly, potassium compounds are used to produce iodised salts. Potassium iodide is suitable for use in refined salts, while potassium iodate is suitable for both refined and unrefined (impure) salts without the addition of extra stabilisers and drying agents.

Studies of the stability of iodised salt using potassium iodate showed that on storage in polyethylene bags for two years there was no significant loss of iodine, as well as negligible iodine loss after boiling of the salt solutions (Chauhan *et al.*, 1992; Silveira, 1993 cited in FAO, 1996).

Cheetham Salt Ltd estimated that production related costs, i.e. the costs of iodine and associated analytical testing, would add approximately 5% to the cost of salt to the food industry.

3.5.1 Margarine

An investigation into the use of iodised salt in the manufacturing of processed foods in South Africa by Harris, Jooste and Charlton (2003) found that iodised salt was being used by a proportion of food companies unknowingly in the manufacturing of common processed foods. This provides an indication that iodised salt may not always cause the adverse effects on products such as changes to stability, colour, flavour and taste suggested by manufacturers. This included two margarine manufacturers with a countrywide scale of distribution. The iodine content of the salt used at one manufacturer was found to be, on average, 39 mg/kg which is within the current voluntary iodine fortification levels used in Australia for table salt of 25-65 mg iodine/kg salt.

3.5.2 Cheese

Iodised salt is used in the production of cheese in Switzerland. Hostettler (1953) cited in West *et al* (1995) concluded that iodised salt in cheese production did not affect the quality. Two previous studies involved Emmentaler and Gruyère cheese in which no difference in quality could be detected. This could be due to the low concentration of iodine effectively present in the product as well as the lack of reporting of differences in cheese quality between different areas of Switzerland that did and did not use iodised salt as a cheese ingredient. Iodine could also be introduced into cheeses by inoculation into cheese milk (Kammerlehner, 1995).

Technological problems can arise when iodine is added to cheeses that are cooked and stretched, for example when used in pizza type cheeses such as mozzarella (*personal communication Dairy Australia*).

3.5.3 Cereals

Cereals and flours are good candidates for iodine fortification as they are used in the preparation of many mixed foods reaching a wide cross section of the population. However, one case has been sited where of an off-flavour was produced in a cake mix prepared with iodised salt using potassium iodide. The cresol from the lemon flavouring reacted with the iodide to form iodocresol which has a very low odour threshold (Sevenants and Sanders, 1984 cited in West, de Koning and Merx, 1995).

Many industries report the successful addition of small amounts of iodine to cereals without any significant technical difficulties (Winger *et al.*, 2005). As products such as breakfast cereals, become more complicated and contain a more diverse array of ingredients, the likeliness of an adverse reaction occurring is increased. The type of processing for many different products will also influence the retention of iodine levels in the food and quality. Further studies are needed to confirm the expected iodine losses in specific breakfast cereals as a result of different processing methods.

3.5.4 Bread

Iodine may be delivered into bread by the addition of iodised salt as an ingredient, as a component of the improver mix or by incorporation into the flour. Iodisation of bread has been carried out in the Netherlands and Tasmania by the addition of 2-4 ppm potassium iodate to the bread improver mix which was already in general use. Iodate has been used in bread production in the past, not as a fortificant but to oxidise the sulphhydryl groups of cysteine residues in the protein to disulphide bridges, thus improving dough quality (West, de Koning and Merx, 1995).

The effect of iodised salt on processing characteristics and quality of white bread was investigated by Kuhajek and Fiedelman (1973) cited in FAO (1996). No abnormalities were reported and retention of iodine throughout processing and storage was 50-80%. There were no reported effects on food quality aspects in relation to sensory characteristics.

There is currently a memorandum of understanding between the Tasmanian Department of Health and Human Services with bakeries for the use of iodised salt in bread making in that State. Salt is usually added to bread at 1-2% of the formulation for taste and for technological reasons as salt interacts with cereal proteins. No technical problems with the baking process, including changes to taste, texture or product quality were reported.

There will be losses of iodine during bread processing steps, especially baking. Limited data exists on the likely iodine losses expected as a result of different food processing situations. It has been estimated that losses in the magnitude of 6 – 20% can occur during processing of cereal-based foods (Winger *et al.*, 2005). Data derived from the Tasmanian fortification program showed iodine losses of approximately 10% in baked bread. Minimal loss of iodine has also been reported in iodised salt subjected to heating (Bhatnagar, 1997).

3.5.6 Canned, Cured, Pickled, and Fermented Products.

Wirth and Kühne (1991), as cited by West, *et al* (1995) investigated the effect of iodised salt on quality of meat products in Germany. Table salt in Germany has contained 15-25 mg of iodine/kg from potassium iodate since 1982.

No effects on processing and sensory characteristics of the products tested were reported. These products included pasteurised sausages, fresh sausage (bratwurst), dry cured ham (Rohschinken) and fermented sausage, prepared using iodised table salt. Iodised nitrite curing salt was used in the production of fresh sausage, cooked cured ham, cooked sausage and fermented sausage (salami), with no effect on sensory characteristics or nitrite content noted. The iodised salt had no reported effect on the formation of nitrosamines in those products studied. Losses of iodine during cooking and storage were noted as varying from 25% for bratwurst to 7% for fermented sausage.

Differences in the characteristics of smoked, salted and cured fermented foods produced using iodised salt and those using unfortified salt were investigated by Azanza *et al* (1998) in the Philippines. In general it was found that iodised salt had no effect on the sensory properties of the products as well as no significant effect on pH, water activity or salt levels. Iodine content increased in all products following salting, ranging from 15.89-755.0%. Consequent processing steps including boiling, heating, drying, smoking, curing/fermenting reduced iodine content by 32.75-93.04%. The only exception to this was nitrite-cured pork, where due to the low temperature during curing and gradual salt uptake, the iodine content was reported to continue to increase.

As there is a significant variation in losses and uptake during processing and storage, the use of iodised salt in processed meat products would require substantial shelf life testing of each individual variety. Processed meat products are not consumed uniformly by all Australians and therefore this may not be a very effective vehicle, in terms of cost to industry or in terms of increasing iodine status in the general population.

3.5.7 *Pickled Vegetables*

Amr and Jabay (2004) reported that iodization was seen to have no effect on the flavour of pickles, but the form of iodine used affects the appearance in terms of darkening and discolouration, as well as the degree of softening. These negative effects occurred with most pickled vegetables when potassium iodate (KIO₃) was used but none were noted when potassium iodide (KI) was used. The final concentration of iodine in the pickled vegetables was the same regardless of the type of salt or form of iodine used. The source of the salt used in pickling vegetables, from the Dead Sea or a natural brine well and whether refined or crude salt was added resulted in minimal effects on the sensory evaluation results.

Doman *et al* (1999) reported on the effect on quality of fermented cabbage using different concentrations of potassium iodide in iodised salt. There was no reported change in quality with potassium iodide used in concentrations up to 6.0 mg/kg. Quality was found to be no different in terms of microflora composition, lactic acid production and sensory properties after seven days of production and ninety days storage.

Therefore, if iodisation of pickled vegetables was to be used as a tool to increase the iodine status of the population, potassium iodide would probably be the preferred form as there would be lesser detrimental effects on the quality of the product.

3.5.8 *Canned Products*

The effect of iodised salt used in some canned products is discussed by West, de Koning and Merx (1995).

Experiments using canned vegetables, soup and baby food showed there to be no effect on the product or the can itself. One exception reported the initial production of an objectionable flavour in canned pork and beans that receded during extended storage.

A previous study by Kojima and Brown (1955) cited in West, de Koning and Merx (1995) on the effect of iodised salt using potassium iodate and iodide on canned fruit and vegetables also concluded that there was no effect on sensory characteristics, colour, flavour, odour or texture.

The use of iodised salt in canned products may be an effective vehicle for iodine, but the effectiveness of delivery of canned foods to the iodine deficient population is not known.

4.0 Iodine Fortification and the Food Industry

4.1 Storage

Studies of the stability of iodised salt using potassium iodate showed that on storage in polyethylene bags for two years there was no significant loss of iodine (Chauhan *et al.*, 1992; Silveira, 1993 cited in FAO, 1996). The stability of iodine in salt is determined by the form of iodine used. Iodate is more stable than iodide, without the addition of extra stabilisers and drying agents. The purity of the salt and the climatic conditions it is stored in can also affect storage. Oxidation of iodine occurs if storage conditions are either humid or highly aerated; involve exposure to sunlight or heat; allow for the presence of impurities or moisture in the salt; or if there is an acidic environment.

4.2 Processing Interactions

It is important to consider the interaction of iodine with other constituents of food, including the role that any naturally-occurring goitrogens may play in the bio-availability of the iodine once digested.

A manufacturer may be required to spend time and money investigating the levels of iodine retention in a product throughout processing and the complete shelf life. The effect of certain processing techniques, including different times and temperatures to achieve pasteurisation, may affect iodine levels.

4.3 Analytical Testing and Quality Control

Manufacturers would be responsible for the validation of levels of iodine in their products to ensure accuracy and consistency. This would be an on-going additional cost. The establishment of quality control procedures in relation to both natural iodine concentration and added iodine salts will also be required within quality assurance programs.

Many different analytical testing methods have been used in different studies with different food products, such as the potentiometric titration method used to quantify the amount of iodine in salt. Standard methods would be required as well as the establishment of monitoring programs by regulatory bodies.

4.4 Labelling Requirements

There will be labelling costs associated with iodine fortification of processed foods. There has been some concern expressed by the food industry in relation to the requirement to include 'iodised' in the product name which may prove problematic considering definitions of products in food legislation. Increased costs to industry in relation to modification of labels / packaging to include fortificant in ingredients list and name of product would not be an on-going cost after the initial change.

5.0 Conclusion

There has been some concern expressed by industry about the effect that the addition of iodine will have on product quality. From this review of literature there have been many cases of successful fortification of foods with iodine with few reported effects on organoleptic qualities.

Salt has been extensively used as a vehicle for iodine fortification. With the widened use of iodised salt in food processing a variety of foods could provide a source of iodine, and may prove beneficial in improving the iodine status of the population. The use of iodised salt in a number of processed foods has been considered in this review, with almost all studies reporting no effect on product quality dependant on source of iodine used.

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