The triple fortification of salt with iodine, iron, and folate using spray dried microcapsules

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INTRODUCTION AND OBJECTIVE

Micronutrient (i.e. vitamin and mineral) deficiencies directly affect an estimated 2 billion people worldwide causing death and impairment (World Health Organization, 2007). The most extensive problems arise in developing countries where people consume micronutrient-poor diets containing little iodine, iron, and folate. Food fortification is more effective than supplementation or dietary diversification to rectify this issue because it does not require active participation by the consumer and is more cost effective. Salt is the most effective food vehicle because it is consumed in constant daily amounts, is generally purchased not of harvested personally, has proven efficacy in the developing world, and has established distribution channels.

As a method to remedy iodine and iron deficiency simultaneously, double fortified salt was investigated. It was found that retaining iodine in salt fortified with iron stored at elevated temperatures and moisture levels required microencapsulation to form a physical barrier able to keep adsorbed water, iron, and iodine apart in the salt (Diosady et al., 2002). In 2011 Romita et al. developed spray dried ferrous fumarate microcapsules for use in coarse iodized salt (Romita et al., 2011). The particles produced through spray dry microencapsulation were too small to be visually detected (<20µm) and were small enough to adhere so salt crystals in the presence of moisture typical of unrefined commercial salt (Romita et al., 2011). Microcapsules that retained the most iodine were composed of 80% dextrin and 20% hydroxypropyl methylcellulose (HPMC) as the coating material (Romita et al., 2011).

The objective of this project was to investigate micronutrient stability in salt fortified with iodine, iron, and folate using spray dried iron microcapsules and spray solutions containing iodine and folate.

MATERIALS AND METHODS

Materials for fortification

Non-iodized refined Canadian salt was donated from Sifto Canada Corp. Folic acid (USP grade) was acquired from Bulk Pharmaceuticals Inc. Potassium iodate (ACS reagent grade) was purchased from Sigma-Aldrich Chemicals. Ferrous fumarate (food grade, mean diameter ~10µm) was donated by Dr. Paul Lohmann Chemicals. Hydroxypropyl methylcellulose (HPMC E15) was provided by Dow Chemicals Co., USA. Maltodextrin was donated by Cerestar, Indianapolis IN.

Iron microcapsule production

Microcapsules were prepared by Dan Romita by spray drying a suspension of ferrous fumarate in coating agents (Romita et al., 2011). The microcapsules contained 9% w/w iron and a coating consisting of 80% w/w maltodextrin and 20% w/w HPMC.

Fortification method

Salt was fortified in a bench-scale ribbon blender made by Les Industries All-Inox Inc., Montreal. Salt was added to the ribbon blender (250g-1000g) and blended for 2 minutes to break down any large salt clusters. Then folic acid and/or potassium iodate were added via solution sprayed through a spray bottle onto the salt. This added 13% moisture. Iron was added in powder form either as unencapsulated ferrous fumarate or as spray dried microcapsules. The salt was mixed for 15 minutes in the ribbon blender and then was taken out and put on sheets to dry overnight.

Table 1: Triple fortified salt formulations

Salt Sample #	Iodine (I) (ppm)	Folic Acid (FA) (ppm)	Iron (Fe) (ppm)	Encapsulated Iron (nFe) (ppm)
1	0	30	0	0
2	30	30	0	0
3	0	0	1000	0
4	0	0	0	1000
5	0	30	1000	0
6	0	30	0	1000
7	30	30	1000	0
8	30	30	0	1000

Stability testing

The salt was stored in Zip-Loc™ polyethylene bags in the dark at 25ºC. The retention of the micronutrients in the different salt formulations was measured 1 year after production.

For iodine quantification iodate is reduced to iodine (I_2) and titrated with sodium thiosulfate using a starch indicator (Method 33.149, Association of Official Analytical Chemists (AOAC)).

The total iron and ferrous iron content was determined by the complexation of ferrous iron with 1,10-

phenanthroline followed by spectrophotometry at 512 nm. To measure total iron a reducing agent (hydroxylamine hydrochloride) was added to convert any ferric iron into ferrous iron before it was complexed with 1,10-phenanthroline.

The folic acid analytical method involved a series of three reactions that converted folic acid into a coloured product. Folic acid was reductively cleaved in hydrochloric acid by zinc. The product was diazotized and then coupled with 3-aminophenol. This was followed by spectrophotometry at 460 nm.

RESULTS AND DISCUSSION

It was confirmed that encapsulated ferrous fumarate retained 10% more ferrous iron than non-encapsulated ferrous fumarate. There was no significant change in ferrous iron retention due to folic acid or iodine in the salt (Figure 1). This may be due to the greater concentration of iron added to the salt compared to that of iodine and folic acid (1000 ppm vs. 30 ppm).

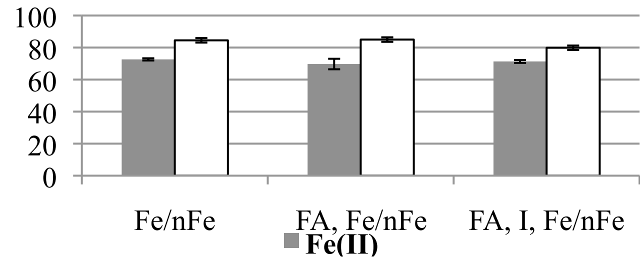

Figure 1: Percent retention of ferrous iron (1 year)

Iodine retention was greatly affected by iron. Without iron, iodine remained very stable in the salt (100% retention ± 3%). With the addition of encapsulated iron only a small amount was retained after 1 year of storage (11% ± 1%). When iron was added without being first encapsulated, iodine was completely lost during 1 year of storage (Figure 2). The loss of iodine is likely due to the redox reaction between iodate and ferrous iron ($2IO_3^-{}_{(aq)} + 12H^+ + 10Fe^{2+} \rightarrow I_{2(s)} + 10Fe^{3+} + 6H_2O$).

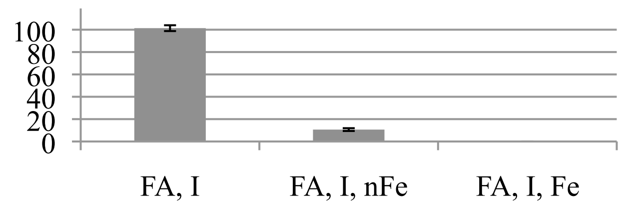

Figure 2: Percent retention of iodine (1 year)

The iodine subsequently sublimes from the salt. Unexpectedly, the microcapsules prevented only some of the iodine loss. This was likely due to the loss of capsule integrity. A large amount of water (13% w/w) was added to the salt when folic acid and iodine were sprayed on the salt. This partially solubilized the microcapsules releasing ferrous fumarate and allowing it to contact iodine.

Folic acid was fully retained in salt fortified with only folic acid (105% ± 6%) and in salt fortified with folic acid and iodine (101% ± 6%). Iron seemed to have a negative effect on folic acid, reducing the folic acid content by more than 20% in all cases. Iodine and iron encapsulation seemed to protect folic acid from degradation. In all salt formulations folic acid retention was greater than 50% and triple fortified salt containing encapsulated iron retained 76% ± 7%. Iodine and folic acid retention would be improved by increased iron capsule integrity. In the meantime adding an overage of folic acid could ensure sufficient folate content for the consumer.

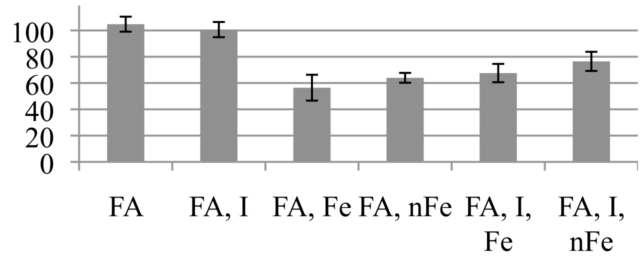

Figure 3: Percent retention of folic acid (1 year)

CONCLUSIONS

The feasibility of iodine iron and folic acid fortification of salt has been demonstrated. The encapsulation of ferrous fumarate used in this trial was unsatisfactory resulting in a large loss of iodine and a lesser loss of folic acid. An increase in the concentration of folic acid and iodine in the spray solution would reduce the moisture added and thus help preserve the capsule integrity, preventing the reactions between iron and the other micronutrients Future work will concentrate on improving iron encapsulation, and reducing the amount of water used in fortifying the salt.

REFERENCES

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