Fortification of Salt with Iron

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ABSTRACT

Widespread prevalence of anemia in India has prompted efforts to introduce iron into the daily diet using salt as the vehicle. Studies have been directed towards using an iron salt that is nutritionally available, does not discolor the salt or affect taste even after long periods of storage in humid environments. Suitable additives have now been found to prevent discoloration of salt fortified with ferrous sulfate. Preliminary nutrition tests being conducted to determine the bioavailability of the iron in fortified salt after several months of storage have shown promising results.

INTRODUCTION

The problem of malnutrition in most developing countries has prompted work on quick and effective methods to combat nutritional deficiencies. While in the long run, the problem must be tackled by development and educational programs to modify food habits, short run measures like food fortification are evoking increased interest. Salt, a universal component of the daily diet consumed by normal adults everywhere is attracting increasing attention as a vehicle for nutrients especially to fortify the diets of the low-income and vulnerable groups of the population in developing countries.

SALT AS A CARRIER OF NUTRIENTS

The feasibility of adding several nutrients like calcium, iron, Lysine, and Vitamin A, through the medium of salt has been under study in India for over five years and a stage now has been reached where at least the basic technical problems of fortifying salt with iron appear to have been overcome. While the fortification of salt with calcium has not met with any major technical problems, nutritionists are still in doubt as to whether the entire population, even if otherwise undernourished, would benefit from such a program. Other additives such as Lysine and Vitamin A have been found to be unstable when stored in moist salt for several months. There is, however, scope for determining methods to prevent the progressive destruction of these nutrients in salt.

There is no question today as to the imperative need to supplement the daily diet with additional iron since anaemia is highly prevalent in most developing countries. It has also been generally acknowledged that the vulnerable groups would benefit most from supplemental iron in their diets. In a country like India logistical problems have prevented the addition of iron salts to cereals on a large scale owing to the relatively lower quantum of centralised milling and the difference in dietary patterns in different parts of the country and for the same individual at different times of the year. Salt, for several reasons, presents itself as an ideal carrier of essential nutrients. Firstly, salt is consumed in all regions of the country, irrespective of dietary patterns with regard to cereals. It is consumed by all normal adults in approximately the same amounts each day. This makes it possible to determine accurately the appropriate level at which a particular nutrient could be added and to control its intake. Secondly, since the production and distribution of salt in the country are planned and regulated by the Government of India, the control of fortification is economically and administratively feasible. Thirdly, salt is well distributed in several preparations and the presence of metabolites which assist in the utilisation of nutrients is ensured.

SELECTION OF AN IRON SALT

The conditions to be satisfied by an iron compound in order to be acceptable for fortification of salt are:

1) It should not discolor the salt over long periods of

storage and at various levels of humidity during storage.

2) It should not add any taste or odour to the salt, i.e. the salt should in no way differ from unfortified salt.

3) The iron in the fortified salt should be nutritionally available after mixing and after months of storage.

4) The addition should be economically feasible.

5) It should not cause any serious problems of drainage and dislocation problems during storage.

There is no iron compound that would by itself satisfy all these requirements. The white, insoluble, relatively stable iron phosphate compounds (like sodium iron pyrophosphate, ferric orthophosphate or ferric pyrophosphate) have been reported by Rao et al. (1971) to be poorly absorbed. On the other hand, the soluble well-absorbed iron compounds (like ferrous sulphate or ferrous citrate) discolor the salt very quickly. It is therefore possible that a solution could lie in either increasing the absorption of the ferric phosphate compounds or preventing the soluble ferrous iron compounds from discoloring salt.

Some nutritionists have suggested the use of a medium like ascorbic acid to improve the bio-availability of the ferric phosphate compounds. Ascorbic acid when fed in large amounts, enhances absorption (Harris and Kellermeyer, 1970). In addition to its ability to help in the reduction of trivalent iron to the divalent state, ascorbic acid, when it is present with trivalent iron in a low pH media, combines with iron to form a soluble ascorbate chelate. However, cost and availability factors may prohibit such a remedy for a large-scale fortification program. In India, for instance, ferric pyrophosphate costs roughly ten times as much as ferrous sulphate and is absorbed to a much lesser extent. In terms of cost per unit of available iron the phosphate salt will be well over twenty times as expensive as ferrous sulphate. Our efforts have mainly concentrated on the alternative solution of preventing the ferrous compound from discoloring the salt. The explanation given for the soluble iron compounds turning color when present in salt is that when they come into contact with moisture (inevitable in crude unprocessed salt in humid environments), they hydrolyse progressively. According to Rollinson (1970) a polymerisation process occurs and the iron compound gets colored yellow or brown. Simultaneously the iron is slowly oxidised to the ferric state. The iron in such a form would be biologically unavailable. Therefore it is necessary to prevent the coloration process in the first place. Encapsulated ferrous sulphate has proved ineffective in India especially because of the common Indian practice of adding salt to food while it is being cooked. At that temperature the encapsulating medium has been found to wear off and discolor food.

The ferrous and ferric ions are always present coordinated with a ligand. The hydroxide ion itself is a good ligand. Hydrolysis could be prevented or retarded, if along with the ferrous sulphate a coordinating agent is present that will compete with the water molecule and combine with the iron compound to form a complex that is not colored and shows no tendency to polymerise.

Another problem to reckon with in India is that the salt (mostly solar salt) is generally impure. It contains as much as 2 per cent calcium and magnesium salts and is therefore especially hygroscopic. The moisture problem is aggravated especially during the humid months of the year. Further, the salt for edible consumption comes in a variety of sizes ranging from half-inch crystals down to a minus 40 mesh powder. The crushed salt used for fortification was course ground (10–20 mesh) and impure, since we wanted a typical sample and did not wish to introduce additional prerequisites like washing and drying of the salt prior to fortification at this stage.

PREVENTION OF COLOR IN SALT FORTIFICATION WITH FERROUS SULPHATE

Attempts were made by Gurunath and Venkatesh Mannar (1973) to correlate color formation with the impurity content in the salt. The only conclusion that has been drawn so far from those tests is that the presence of higher amounts of magnesium chloride initially accelerates color development in iron-fortified salt probably because of its hygroscopic nature. The approximate impurity levels in the salt used were: $MgCl_2$– 0.83%; $MgSO_4$– 0.39%; $CaSO_4$– 0.75%. However, over a period of 12–14 weeks there is no appreciable difference between samples of fortified salt prepared with and without magnesium chloride. Calcium sulphate and magnesium sulphate appear to have no effect, at least on color development. Quantities of calcium carbonate in excess of 3,000 ppm give iron-fortified salt a brown tinge.

In an attempt to prevent color development in impure salt fortified with iron, sodium hexametaphosphate (SHMP) used commonly for water treatment was recommended as a coordinating agent by Diamond and Venkatesh Mannar (1973). A sufficiently low pH that would further discourage the water from reacting with the iron was maintained by the addition of sodium bisulphate. The best formula seemed to be an optimum combination of additives rather than a minimum requirement. Samples of fortified salt were prepared with additive content in the following ranges:

Ferrous Sulphate (dried)	2500 ppm
Sodium Hexametaphosphate	500 to 2500 ppm
Sodium Bisulphate	0 to 2500 ppm

The exact mechanism which prevents color development can only be postulated. Obviously the iron complexes with the coordinating phosphate ions as reported by Van Wazer & Callis (1958). Also, over a period of time there is a change in the state of iron from ferrous to ferric. There is also a gradual depletion in the soluble iron content. These are apparently negative developments that would lead one to believe that a diminution in the nutritional availability of the iron in the salt occurs over a period of time. However, nutrition tests on a sample containing 2500 ppm ferrous sulphate, 1000 ppm SHMP and 500 ppm sodium bisulphate, have revealed that the presence of the phosphate and bisulphate do not impair the bio-availability of the ferrous sulphate when administered along with the salt through a normal meal. The tests were conducted immediately after the fortified salt sample was prepared and then after four months of storage. However, salt prepared with the above formula does develop a color over a period of time.

Further work by Gurunath and Venkatesh Mannar (1973) established that salt containing additives according to the following composition is resistant to color development even when the salt used is impure and contains as much as 5 per cent moisture.

Ferrous Sulphate (dried): 2500 ppm; Sodium Bisulphate: 1500 ppm; SHMP: 2500 ppm.

Nutrition tests on samples of fortified salt containing these increased levels of phosphate and bisulphate are still in progress at the time of presenting this paper. In vitro solubility tests in dilute hydrochloric acid as outlined by Pla and Fritz (1970) conducted on the fortified salt samples show that the iron remains 100 per cent soluble in dilute acids even after seven months of storage in fortified salt.

Attempts are being made to replace the SHMP by a cheaper and/or more effective coordinating agent. Tests using sodium phrophosphate and sodium acid pyrophosphate as coordinating agents have not been effective even with pH control. Orthophosphoric acid has been reported by Gurunath & Venkatesh Mannar to be a good substitute for SHMP and sodium bisulphate since it combines the role of acid medium and coordinating agent.

Tests with dextrose at a level of 0.1 per cent showed that it is only marginally effective in retarding oxidation. However, it has no effect on color development. The marginal benefit in the retardation of oxidation is more than offset by the cost of dextrose addition.

All the chemicals mentioned above are already being used as food additives in different parts of the world. For instance SHMP is used as an emulsifier, sequestrant and texturiser. Sodium bisulphate is used as an acid medium. Orthophosphoric acid is being used in a number of soft drinks, jams and jellies to react with and render colorless any traces of iron salt that may be present.

The mixing procedure by itself is the conventional method of continuous dry mixing in a screw. The salt and the other additives (as a premix) are introduced through suitable feeders. Moisture when present in the salt up to a level of 5 per cent has been found not to hinder mixing. It has in fact helped the operation and obviated the need for any alkaline fillers which would introduce fresh complications. Continuous mixing trials have shown the mixing to be fairly uniform. An analysis of several spot samples has given a mean of 750 ppm iron (theoretical value: 800 ppm iron) and a standard deviation of 100 ppm.

In India edible salt is usually packed and transported in jute bags. The effect of long storage of fortified salt in jute bags in a highly humid environment has been studied. Although there is a certain amount of drainage in the bag there is no excessive segregation of iron at any point. After seven months of storage of fortified salt in a jute bag the range of iron content at different points in the bag was found to be between 500 and 1000 ppm for an initial addition of 800 ppm iron in the salt. This is probably because most of the iron becomes water insoluble after a few weeks of storage.

TESTING OF FORTIFIED SALT

After the nutritional availability studies are completed, a number of other tests are being planned to ensure that the fortified salt will be acceptable to everyone. Chief among these are the village level acceptability tests, nutritional impact tests and cooking tests in a wide range of Indian recipes.

LEVELS OF IRON FORTIFICATION AND COST

In India the average daily consumption of salt by a normal adult is between 15 and 20 grams. Ferrous sulphate (dried) when added at a level of 2500 ppm would introduce elemental iron at a level of 800 ppm. Assuming an average absorption of 5 per cent of the iron when consumed with a normal meal, it has been estimated that this level of fortification would ensure the normal adult with a supply of approximately 0.6 mg of absorbed iron every day which is slightly over a third of his daily iron requirement. It must be mentioned at this point that any such iron fortification program can be expected to have only a long term salutary effect on the state of iron deficiency. It cannot be expected to produce spectacularly quick results in curing cases of acute anemia or cases where certain sections of the population (like pregnant and lactating mothers) need additional iron.

At the above level of fortification, the cost of chemicals, depreciation on mixing equipment, labour, etc. has been found to be less than 2 US cents per head per year. It is clear that there can be no cheaper or more effective means of providing iron to the entire population of a developing nation like India than through the medium of salt.

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