**Fortification Of Milk And Milk Products For Value Addition**

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### Introduction

Food fortification is thought to be a highly effective solution and among the most cost effective public health interventions currently available. It may be defined as the addition of one or more essential nutrients to food whether or not it is normally contained in the food, for the purpose of preventing /correcting a demonstrated deficiency of one / more nutrients in the population or specific population groups (Codex Alimentarius Commission, 1994). It is practiced in those areas where the problems of malnutrition are prevalent.

According to FAO/WHO guidelines (1995) essential nutrients may be added:  
(i) to replace losses that occur during manufacture, storage and handling of food (restoration). For example the removal of cream from milk takes almost all the natural vitamins A and D and therefore skimmed milk may be fortified with the same vitamins at levels as fluid whole milk. (ii) To ensure nutritional equivalence in imitation or substitute foods. (iii) To compensate for naturally occurring variations in nutrient levels. For instance, milk and butter are subjected to seasonal variations in vitamins A & D contents. Some dairy products are fortified with the vitamins A & D in order to maintain constant vitamin levels. (iv) To provide levels higher than those normally found in a food. For example, margarine is fortified with vitamins A & D (in western countries) to render it nutritionally equivalent to butter, and (v) to provide a balanced intake of micronutrient in special case (dietetic foods) for example infant formulas, special food for athletics, medical food etc.

**General criteria for fortification**

- The intake of nutrients is below the desirable level in the diet of significant number of people.
- The vehicle used for fortification should be consumed in significant quantities by target population.
- Addition of nutrient should not create an imbalance of essential nutrients.
- The added nutrients should be stable under proper conditions of storage and use.
- Biological availability of added nutrients should be high.
- There should be reasonable insurance against excessive intake to a level of toxicity.

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**Milk and milk products as a suitable vehicle for fortification**

Milk in its natural form is almost unique as a balanced source of man's dietary need (Table 1). The various steps in processing and storage have a measurable impact on some specific nutrients. Milk also provides a convenient and useful vehicle for addition of certain nutrients to man's diet and has following benefits:

- Since milk is centrally processed so that the quality control can be effectively implemented.
- Milk and milk products are widely consumed regularly in predictable amounts by people of all age groups.
- Cost is affordable by target population.
- The stability and bioavailability of the added micronutrients to milk remains high.
- Since milk is nearly a complete food and all nutrients exist in almost fully available form, the bioavailability of added nutrients remains high.
- Addition of fortificants usually caused minimum change in colour, taste and appearance.

**Nutrients generally added to milk**

Liquid milk fortification with vitamins A and D is mandated in several countries. B-carotene is added as a colour-enhancing agent to some milk products such as butter. Dried milk is often fortified with vitamins A and D, calcium, and iron. Milk based infant formula and weaning foods are fortified with a range of vitamins, minerals, and other nutrients such as polyunsaturated fatty acids. Powdered milk used for complementary feeding in Chile is fortified with vitamin C, iron, copper and zinc.

**Fortification of milk & milk products with Vitamins**

Under ambient conditions the water soluble vitamin C and vitamins of the B-complex group such as thiamin, riboflavin, vitamin B₆, niacin, pantothenic acid, folic acid, biotin and vitamin B₁₂ are powdered and thus relatively easy to work with when producing most dairy products. The fat soluble vitamins which include vitamin A, D, E and K, however, exist either as an oil or as crystals, which may cause processing difficulties during the production of certain types of dairy products (Mortensen and Gotfredson, 1996).
One of the problem encountered with the vitamins, is their limited stability in presence of heat, humidity and oxygen. Among the water soluble vitamins, vitamin C, folic acid, vitamin B_6 and vitamin B_12 are the less stable. While in the case of fat soluble vitamins vitamin A, D and E are least stable.

In order to improve the stability of these vitamins, a number of different coating technologies have been developed. One of the most important methods to protect the fat soluble vitamins is microencapsulation, which results in a highly sophisticated powder, where the vitamin is kept protected from degradation by the coating material used for the encapsulation. During microencapsulation, the fat soluble vitamins are brought from the form of oil or a crystal – which in some processes would be difficult to handle – to the form of a free flowing powder much easier to handle and mix with other dry ingredients (Mortensen and Gofredson, 1996).

When two or more vitamins are added to a food product at the same manufacturing stage, this is commonly done in the form of premix or as blend. Premix is a homogenous mixture of desired vitamins in a dry powder form, whereas a blend is the same for the fat soluble vitamins, but in an oily form. A premix can consist of both water soluble and fat soluble vitamins and carotenoids, in which case the fat soluble vitamins have to be microencapsulated.

**Fortification of milk and milk products with iron, calcium and other minerals**

Selection of an appropriate mineral fortificant (iron, calcium etc) is based on its organoleptic considerations, bioavailability, cost and safety. The colour of iron compounds is often a critical factor when fortifying milk and milk products. The use of more soluble iron compounds often leads to the development of off-colours and off-flavours due to reactions with other components of the food material. Infant cereals have been found to turn grey or green on addition of ferrous sulphate. Off-flavours can be the result of lipid oxidation catalysed by iron. The iron compounds themselves may contribute to a metallic flavour. Some of these undesirable interactions with the food matrix can be avoided by coating the fortificant with hydrogenated oils or ethyl cellulose (Jackson and Lee, 1991).

Bioavailability of iron compounds is normally stated relative to a ferrous sulphate standard. The highly water soluble iron compounds have superior bioavailability (Richardson, 1990). Bioavailability of the insoluble or very poorly soluble iron compounds can be improved by reducing particle size. Unfortunately this is accompanied by increased reactivity in deteriorative processes. The problem of low bioavailability of some of the less reactive forms of iron is often circumvented by the use of absorption enhancers like, ascorbic acid, sodium acid sulphate and orthophosphoric acid, added along with the fortificant.

The other important mineral for the fortification of milk and milk products, which has been studied, is calcium. Several commercial calcium salts are available for calcium fortification, which include carbonate, phosphate, citrate, lactate and gluconate. In general, organic acid salts of calcium are more bioavailable than inorganic salts (Labin-Godscher and Edelstein, 1996). The pH of the milk should be taken care of during Ca fortification. Manufacturers of calcium fortified milk products should consider adding, magnesium, riboflavin and perhaps vitamin D as well, in amounts that would normally be obtained in a serving of vitamin D fortified milk (Weaver, 1998).

Milk and milk products can also be fortified with a range of other mineral salts such as Mg, P, Zn, Cu and Mn. Prudent selection of mineral compounds is based largely on consideration of mineral reactivity and solubility of the salt. To overcome problems of flavour, texture and colour deterioration due to addition of minerals, some companies have engineered new fortificant preparations, which generally involve the use of stabilisers and emulsifiers to maintain the mineral in solution (FAO, 1995).

**Technology For Fortification**

**1. Liquid milk**

The technology of milk fortification is relatively simple and no additional equipments are needed or can be practiced with minor modifications in the existing plant. Mineral/vitamin fortification can be practiced at several stages in the production. But liquid milk is usually fortified prior to pasteurization or ultra-heat treatment. Homogenization is essential for oily preparations of vitamins. Usually two methods of additions are practiced i.e. batch process for small operations and metered additions for continuous process. A metered injection of the vitamin preparation upstream to the homogenizer has been the standard set up in continuous operation plants (Cornell University, 1994).

Oily preparations are diluted with 10 parts of warm oil (45 – 50°C), usually butter oil and homogenized with a suitable quantity of skim milk or it can be mixed with appropriate quantity of milk and cream and finally homogenized. In the case of water soluble or water dispersible micronutrients, a premix can be made by diluting the nutrients to 20 times their weight with milk at 45°C, followed by stirring and thorough mixing (USAID, 2001).

A simple procedure for fortification of skim milk with vitamins A without using homogenizer was developed by Bector and Rani (1998). This process is basically a batch process and is suitable for small plants of low capital cost.

Many iron compounds have been assessed in the fortification of pasteurised whole milk. The best fortification procedure was judged to be the addition of ferric ammonium citrate followed by pasteurisation at 81 °C. In this way fortified milk containing 30 ppm iron was found to be acceptable after 7 days storage. Levels of vitamin E, vitamin A and carotene were not affected by the presence of iron. At pasteurisation temperatures below 79 °C off-flavours developed due to the formation of iron...
to lipolytic rancidity (Edmondson et al, 1971). De-
Aeration of the milk prior to the addition of iron
compounds was also found to reduce flavour
problems. In the production of iron fortified
evaporated milk, ferric orthophosphate was shown to
be useful (FAO, 1995).
Calcium fortificant preparations including stabilizers
and emulsifiers have been used for fortification of
milk and milk-based beverages. It maintains calcium
in suspension so as to improve mouth feel and
appearance of products (FAO, 1995). In Germany a
milk-based fruit beverage has been marketed which
is fortified with calcium, phosphorous as well as
vitamins A, E, B and C.
Dried milk:
Here particle size of the fortificant as well as density
of the fortificant has to be taken care as large and
heavier size particles will lead to separation. In
order to achieve stability of vitamins, the safest way
to fortify dried milk is to blend dry forms of premix
with the dried milk powder, thereby protecting the
effect of microencapsulation. However, this requires
an effective mixing system. If blends are used, they
are added directly to milk, provided homogenization
is done before spray drying. If vitamins are added
before spray drying, overage addition (Table 2) will
be necessary in order to compensate the losses
(Mortensen and Gottfredsen, 1996).
Iron fortification of powdered non-fat dry milk, ferrous
sulphate at a level of 10 ppm was found to be stable
for a period of 12 months. Ferric ammonium citrate
and ferric chloride at a level of 20 ppm iron in the
reconstituted product gave acceptable results (FAO,
1995).
Infant Formulas
The mineral content of cow milk, from which many
formulas are produced, is highly variable. Production
methods have been adapted to control this source of
variability. Operations have been included which
remove most of the minerals, but at the same time
some vitamins and other components of the milk are
lost: technologies used include ion exchange, ultra
filtration, electrodialysis, reverse osmosis and gel
filtration. Mineral compounds are then added at the
required levels. There must be careful selection of
mineral compounds added to the formulas, as cereal
products are highly susceptible to lipid oxidation
during storage. The use of ferrous fumarate and
ferrous succinate is recommended for fortification of
infant cereals as they gave rise to no objectionable
flavours/odours or colours on storage. Ferrous
sulphate coated with hydrogenated fats, mono- or
diglycerides and ethyl cellulose caused discoloration
on reconstitution with hot milk and hot water.
Although some allowance is made for the natural
vitamin content of the ingredients used, most of the
vitamins are added to the formula. The Codex
Alimentarius Commission (FAO/WHO, 1994) has
published an advisory list of mineral salts and
vitamin compounds which can be added to formulas.
Predetermined excesses of vitamins have to be
added to allow for processing and storage losses.
UHT processing followed by aseptic packaging has
been preferred to in-can sterilisation since less
nutrient losses occur in the former case. Losses have
been noted particularly for vitamin C, thiamin, folic
acid and vitamin B6.
Iron absorption from formulas has been reported to
be 5-10% compared to 50% for human milk. It has
been suggested that bovine milk proteins or elevated
calcium and phosphorus levels account for this
difference. Zinc levels in formulas are also higher
than in human milk to make up for reduced
bioavailability.
Ice-cream:
The unit operations used in the manufacture of ice-
cream is not highly destructive to vitamins. Vitamins
are added in the dry form to the mix. Since whipping
and consequent operation of the mix is carried out
around freezing temperature, oxidative losses of
vitamins are minimized. The greatest processing
losses, which occur during manufacture of fortified
ice-cream, are during pasteurization of ice cream
milk. Calcium enriched ice-cream is also available in
USA and is marketed under the name of TruCal.
Fermented milk products:
In the production of yoghurt, the low pH renders it
unsuitable as a carrier of vitamins such as vitamin A.
Water soluble vitamins are best used in a
encapsulated form, protected for odour and flavour
considerations. Some vitamin losses can occur through
metabolism by microorganisms during fermentation (O’Brien and Roberton, 1993). The
sensory quality of iron fortified yoghurt was
acceptable when tested by a consumer panel. No
significant difference in the appearance, mouthfeel,
flavour, or overall quality was observed between iron
fortified and unfortified yoghurts (Hekman and
McMahon, 1997). In Germany, enrichment of cheese
with iodine through the use of iodised salt has been
approved.
Considerations While Fortification Of Milk & Milk
Products
1. Bioavailability of commercial preparations:
Bioavailability of different compounds facilitates the
selection of the optimal compound. Bioavailability
refers to the rate of absorption and utilization of a
nutrient from a given matrix.
2. Nutrient-nutrient reaction: Interaction among
the nutrients and other food components is a key
factor in nutrient addition. For example, Vitamin C
will improve the absorption of iron (Kiran et al,
1977). On the other hand, the iron will accelerate
vitamin degradation. Fortification of calcium in milk
may interfere with absorption of iron or zinc
(Weaver, 1998).
3. Nutrient-matrix reaction: The added nutrient
must not react with any component of the milk. For
example, iron is a pro-oxidant and can accelerate
the development of fat rancidity, destroy some of the
vitamins and form coloured products.
4. Shelf-life & packaging: Many of the fortified milk
and milk products may have limited shelf life and
thus may need different types of packaging which
can be either oxygen impermeable or opaque to
FORTIFICATION OF MILK AND MILK PRODUCTS FOR VALUE ADDITION

light. This is particularly true for the fortification of liquid milk with vitamin A as vitamin A fortified milk develops off flavour within 6 h when exposed to light, compared to 12 h for control (Fellman et al, 1991). All the fortified products require proper labelling on the pack.

5. Process considerations: The stability of all the vitamins is well known during various processing conditions and the same knowledge can be applied while processing the vitamin fortified milk.

6. Cost factor: Cost may not be a crucial factor in the manufacture and marketing of fortified milk and milk products.

7. Safety factor: There should be sufficient insurance against excessive intake of the fortificant. Unlike water soluble vitamins, fat soluble vitamins exhibited toxicity at higher concentrations.

Conclusion

Fortification should not alter the organoleptic properties (taste, smell, colour, consistency) and shelf life (conditions related to storage, transport) of the product. Often there is a delicate balance between bioavailability and other properties of fortified food. Milk and milk products provide a convenient and useful vehicle for fortification with micronutrients. The risks associated with fortification are minimal except if good manufacturing practices are not followed and only isolated incidents of this type have ever been reported. Improved understanding of interactions between food ingredients and health and ingenuity of food technologists in food formulation and fabrication will contribute to the advances in food fortification.

References


### FORTIFICATION OF MILK AND MILK PRODUCTS FOR VALUE ADDITION


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### Table 1

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<th>Quantity /Litre</th>
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(OMNI, 2001)

### Table 2

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<td>Vitamin E (IU)</td>
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<tr>
<td>Vitamin K (µg)</td>
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<tr>
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(OMNI, 2001)