Sources of thiamine

Distribution in foods

Thiamine is practically present in all plant and animal tissue, but most contain only low concentrations of the vitamin (see Table A, Annex 3). In plants, thiamine occurs predominantly as free thiamine and in animals almost entirely (95-98%) in phosphorylated forms, the predominant form being thiamine pyrophosphate (Combs,1992). The richest source of thiamine is yeast. Cereal grains, however, comprise the most important dietary source of the vitamin in most human diets. For example, even in the USA and the UK, cereals contribute 52% and 48% respectively of the total thiamine intake followed by meat products in the USA which provide 21% of the daily thiamine intakes (USDA, 1995); and by vegetables in the UK, which provide 18% of the daily thiamine intakes (Anderson et al, 1996).

Thiamine is very unevenly distributed in the kernel of whole grain; the aleuron layer and germ are much richer than the endosperm; the scutellum (the thin layer between the germ and the endosperm), constituting only 1.5% of the weight of the whole kernel, is richest of all and usually contains 50 - 60% of all the thiamine in the kernel. Therefore, milling to degerminate grain yields a product of substantially reduced thiamine content. In highly milled flour only about 70 % of the grain is included and the thiamine content of such a flour is about 0.13 mg/100 g as compared to flour of 80–85% extraction which contain 0.32 mg/100 g. Table 11 comprises the percentage of daily thiamine requirements obtained from bread made from 70% extract and 95% extract wheat flour.

Table 11. Bread as a source of thiamine

Type of bread	Percent of daily requirements supplied (RDA as 1.2 mg)
200 g of unenriched white bread (70% extract flour)	10
200 g of whole wheat bread (95% extract flour)	50

Source: Adapted from Marks (1975)

Rice, in the brown form, has a somewhat lower thiamine content; 0.33 mg/100 g, than the best whole wheat. In highly milled white rice only about 0.08 mg/100 g remains and this may be further reduced by half by washing the rice before cooking. Hand-pounded rice is rarely as white as machine-milled rice and its content of thiamine is 0.16 mg/100 g (FAO, 1964).

Pulses contain about 0 40–0.80 mg thiamine/100 g. In many areas where rice is the staple, they represent one of the most feasible options to provide for adequate thiamine intakes on polished rice diets. Fresh potatoes contain 0.10 mg of thiamine/100 g but since their water content is about 80%, this is equivalent to 0.35–0.40 mg of thiamine/100 g of air-dried matter. Cassava and other roots are less rich in thiamine and cassava flour does not even contain detectable amounts of thiamine.

Cow's milk contains about 0.04 mg of thiamine/100 g but as it is 87% water it is among the thiamine rich foods on a dry weight basis. Pasteurisation of milk destroys about 10% of the thiamine. Human milk contains on average ⅓ as much thiamine as cow's milk.

In conclusion, nearly all living tissues contain thiamine and some thiamine is therefore derived from almost all articles consumed as food. It is only with refined cereals ie. white flour, white rice, degerminated maize meal, cereal starches, cassava and sago, as well as in products made from them, that the thiamine content is too low to support human life

Other sources of thiamine

Intestinal bacteria synthesise thiamine and there is evidence that the requirements of thiamine may be lowered to some extent on diets corresponding to the increase in synthesis by intestinal bacteria. Since the microbiological character of the intestinal flora is influenced by the composition of the diet, the vitamin requirements might change with the proportions of dietary carbohydrate, fat, and protein (Bhuvaneswaran and Sreenivasan, 1962).

It has been reported that allicin in garlic reacts with thiamine to form alithiamine which is more readily absorbed in the intestine, is more stable than thiamine and is not decomposed by thiaminase (Williams, 1961).

Fermentation increases some vitamin B levels (Uzogara et al,1990) and has been reported that a thiamine-deficient diet when supplemented with milk curds appears to increase the intestinal synthesis of thiamine as shown by an increase in urinary and faecal thiamine excretions (Bhuvaneswaran and Sreenivasan, 1962).

Thiamine in breast milk

The literature, particularly that over the last two or three decades, documents infant beriberi as the only serious form of malnutrition which occurs in breast-fed infants receiving adequate quantities of milk from thiamine-deficient mothers. The maternal diet has been shown to be the principal determinant of the amount of thiamine transferred from the mother to the breast milk (see Table 12)

In 1962, based on a study in Manila, Salcedo reported thiamine values ranging from 18.2 μg to 212.1 μg thiamine per litre breast milk from apparently healthy mothers; the average thiamine content being 96.5 μg/litre breast milk If it is assumed that the average daily milk intake of an exclusively breast-fed infant between 1-5 months of age is approximately 750 ml, the expected daily intake of thiamine would therefore have been 72.3 μg or 0.072 mg per day which does not cover the minimum daily requirement of 0.17 mg/day necessary to prevent deficiency (National Research Council [US], 1989).

In the 1930s, substances such as methyl glyoxal were extracted from the breast milk of thiamine deficient women that were later identified as intermediate toxic products in the metabolism of carbohydrates as a result of their incomplete oxidation. It was reported that after ingestion of milk containing such intermediate products, the infant tries to get rid of them partly by excretion

Table 12. Thiamine content of diet and breast milk of lactating women in India

Range of thiamine intake (mg/day)	Mean thiamine intake (mg/day)	Mean thiamine content of milk (μg/litre)
0.09–0.26	0 21 ± 0.01	115.1 ± 0.78
0.26–0.46	0.36 ± 0.02	115.9 ± 1.06
0.46–0.76	0.58 ± 0.01	131.6 ± 1.00
0 76–2.74	1.23 ± 0.29	158.6 ± 1.14

Source: Bhuvaneswaran and Sreenivasan, 1962

but mostly by further oxidation to their ultimate end products. For this purpose, thiamine, which is not sufficiently available, is absolutely essential. Due to lack of thiamine, the toxic products accumulate and cause infantile beriberi or breastmilk intoxication, as it was also called (Fehily,1941;1944).

Several studies were carried out to look at the thiamine contents of breastmilk in various groups of women (see Table 13). Valyasevi and others (1968) reported levels between 93 μg/litre and 149 μg/litre in Thailand. Comparative figures for thiamine content of breastmilk in India were reported as 153 μg/litre and in the USA. as 142 μg/litre. The average figure for the thiamine content of breastmilk as stated by Jelliffe and Jelliffe (1978) is 160 μg/litre. A study carried out in 1980 by Nail and others (1980) looked at healthy, well-nourished, middle-class American women and came up with a figure of 138 μg thiamine/litre breastmilk. They also reported a significant increase in the thiamine content of breastmilk in the first month of lactation. After 43 days of lactation the thiamine levels were 220 μg/litre.

Table 13. Thiamine content of breastmilk in various groups of women

Groups of lactating women	Mean thiamine content of milk (μg/litre)
India[a]	153
Thailand[a]	93–149
U.S.A.[a,b]	142, 138

[a] Valyasevi et al (1968), [b] Nail et al (1980)

Table 14 suggests guidelines for assessing breastmilk thiamine levels in lactating women. The assessment of the thiamine content of breastmilk together with the mortality figures of infants give valuable information on the existence of thiamine deficiency in a community.

Table 14. Proposed criteria for assessment of breastmilk thiamine levels

Thiamine status	Breastmilk thiamine (µg/l)
Normal range	100-200
Marginally deficient	50-99
Severely deficient	<50

Criteria drawn from Salcedo J, Ann N Y Ac Sci. 1962, 98 Art. 2: 568-575, Concepcion I, Dee RL Phil. J Sci. 1949, 78 373, NHMRC Med. J Aust 1978, 1,232-235, Thanangkul O, Whitaker JA Amer. J Clin Nutr 1966, 18, 275-277; Valyasevi A, Vimoksant S, Dhanamitta S J. Med Ass. Thai. 1966 51, 348-353

Factors influencing content and utilization of thiamine in foods

Stability in foods

Losses

Thiamine is water soluble and is susceptible to destruction by several factors including.

- neutral and alkaline conditions
- heat
- oxidising and reducing agents
- ionizing radiation

Thiamine is stable at low pH (pH under 7), but decomposes when heated particularly under non-acidic conditions. Protein-bound thiamine, as found in animal tissues, is more stable. Thiamine is stable when stored frozen; however, substantial losses occur during thawing.

Table B, Annex 3, shows examples of thiamine losses in food processing Losses of thiamine during the commercial baking of white bread, which is between 15 to 20%, is partly due to the yeast fermentation which can convert thiamine to co-carboxylase which is less stable than thiamine (Berry Ottoway,1993). According to a study reported by Marks (1975), the loss in the crust was 30% and that in the rest 7%; rusks, baked twice, lost 40–50%.

Thiamine is very sensitive to sulphites and bisulphites, especially at a high pH. Consequently there are large losses of the vitamin in vegetables blanched with sulphite, and in meat products where sulphites and bisulphites are used as preservatives. Berry Ottoway (1993) reported a thiamine loss in cabbage of 45% in sulphite-treated blanching water compared with 15% in untreated water. Where the pH is low, such as in citrus fruit juices, thiamine losses are considerably less The practice of adding sodium bicarbonate to peas or beans for retention of their colour in cooking or canning results in large losses of the vitamin due to the alkaline environment.

Thiamine is also decomposed both by oxidizing and reducing agents eg. in the presence of copper ions. A comprehensive study of heat processing in tin and glass containers showed significant losses of thiamine; 50% of thiamine was retained after processing and the levels reduced to between 15–40% after 12 months storage (Berry Ottoway,1993). Prolonged dehydration of fruits and vegetables resulted in a loss of 30–50% of thiamine (WHO, 1967).

Thiamine is also cleaved by residual chlorine in proportion to the rise in temperature, rise in pH and concentration of residual chlorine. During the cooking process thiamine in rice is lost because of residual chlorine in the cooking water. The study undertaken by Yagi and Itokawa (1979) shows that there is a loss of 65% of thiamine in polished rice that has been washed and cooked in water containing 0.2 ppm chlorine compared to a loss of 45% of thiamine in polished rice washed and cooked with distilled water containing no chlorine. The thiamine content of raw polished rice is 1 09 +/- 0 03 μg/g and about 45% thiamine losses are expected during the washing and cooking processes. Using chlorinated water to cook rice increases the losses of thiamine from the rice by 20%. These extra losses can make a difference in populations where the intake of thiamine is marginal.

One kilo of raw polished rice contains on average 1.1 mg thiamine and would provide the daily requirement of thiamine. If the rice is cooked it would however only contain about 0.6 mg thiamine, and if chlorinated water is used, the thiamine content of the cooked rice would only be 0.38 mg.

The lime treatment of maize, as practised in Mexico and Central America, causes considerable destruction of the thiamine present in maize, although this process improves the bioavailability of niacin (WHO, 1967).

Interaction with other micronutrients

The fortification and the enrichment of products using more than one added vitamin can increase the possibility of mutual interactions of the vitamins. Most of the work carried out in this area has tended to concentrate on both the stability and the solubility of the vitamins in aqueous multivitamin solutions Thiamine has been shown to have a significant effect on the stability of folic acid, particularly in the pH range of 5 9 to 7. The decomposition of thiamine can also increase the breakdown of vitamin B_{12} (cyanocobalamin).

Vitamin C appears to play a protective role if it is consumed together with thiamine. In animal studies the addition of large amounts of vitamin C to a purified diet reduces the requirement for thiamine Five percent vitamin C added to a thiamine-free diet prevented or delayed the onset of thiamine deficiency signs (Bhuvaneswaran and Sreenivasan, 1962) However, vitamin C supplementation of the diets of thiamine-deficient rats maintained normal ascorbic acid blood levels but was without effect on blood pyruvate levels.

Recommendations to reduce losses

Thiamine losses from cereals could be reduced drastically if flours of higher extraction rates are used, for instance, for baking bread. Rice would retain more thiamine if it were not highly milled. However, people usually prefer refined flours and polished rice; changing their preferences and food habits is known to be extremely difficult Many countries have therefore opted to enrich or fortify refined products with the necessary vitamins.

Thiamine and other vitamins can be retained in rice by the process of *parboiling*, which is an old technology first used in India. Rice in the husk is soaked in water, steamed at atmospheric pressure for 20 to 30 minutes, dried in the sun and subsequently pounded or milled. The steaming splits the husk, making its separation easier, and this was probably the original purpose of parboiling More importantly, steaming causes thiamine and other nutrients to migrate from the outer layers into the endosperm, so that removing the outer layers by milling does not denude the grain of thiamine Parboiling also has the effect of making the thiamine less accessible to water when rice is washed before cooking. Parboiled rice may be milled to a high degree and yet retain enough thiamine to prevent beriberi as evidenced by the absence of beriberi in areas in India where parboiled rice is generally consumed.

Other rice eating communities in South-East Asia have never adopted this method of processing rice and do not like the taste and consistency of parboiled rice. Williams (1961) has enumerated additional advantages of parboiling: (i) parboiled rice is not extensively attacked by weevils since the glazed surfaces are hard enough to resist the weevils' bite, (ii) the rice grows rancid more slowly than under-milled rice because its enzymes have been destroyed by the heat; (iii) due to the toughening of the rice grain the amount of breakage is reduced during subsequent milling. In the 1940s, a method based on parboiling was developed in the U.S.A. and parboiled rice was produced on a large scale

The losses that occur during the preparation of food can also be minimized. Ideal food-preparation and cooking methods for the preservation of thiamine are as follows:

- Use the minimum amount of water for the preparation of vegetables and do not discard the cooking water.
- Cook for the minimum amount of time possible, a high temperature for a short time is preferable.
- Cover the pot with a lid to shorten cooking time.
- Storage of raw foods should be kept to the minimum possible and cooked foods should not be stored.
- Wash vegetables before cutting them.
- If possible rice should not be washed before cooking. If necessary, rinse once only with a little cold water.
- Do not cook rice with excess water that needs to be discarded.
- Use parboiled rice where available.

Nutrition education messages based on the above guidelines can contribute to keep losses of thiamine at a minimum. This can play an important role in situations where the intake of the vitamin is marginal and subclinical beriberi is prevalent

Anti-thiamine factors

Thiamine in foods can be destroyed by anti-thiamine compounds that occur naturally in food or are produced in food as a result of microbial or other action. Dietary analyses may indicate adequate intakes of thiamine, but do not take into consideration the influence of anti-thiamine factors in the diet that may affect the requirement of the vitamin. Studies indicate that situations may exist where such factors may influence the availability of the thiamine present in the food.

An early documented case of thiamine deficiency resulting from the ingestion of food containing such thiamine antagonists was that seen on a fox farm owned by Mr. Chastak in the 1940's. The neurological disorder in the commercially raised foxes fed a diet containing about 10% raw carp was referred to as 'Chastak paralysis'. The condition was brought on by a thiamine-degrading enzyme (thiaminase) present in fish gut tissue. Cooking the fish prior to feeding them to the foxes prevented occurrence of the syndrome, apparently by heat-denaturation of the thiaminase. Thiaminases are present in the raw tissues of many fishes, chiefly fresh water fishes but also in Atlantic herring. These are heat labile and can be effective antagonists of the vitamin when consumed without heat treatment (Combs, 1992).

In the Philippines, the Tagalog word for beriberi is 'bangungut' which means nightmare and classically death occurs in sleep after a heavy meal consisting of rice and fish (Lonsdale, 1990). The thiaminase in the fish may compound an initial marginal dietary thiamine deficiency and can be fatal.

Probably the first description of thiaminase poisoning in humans was documented in the diaries of explorers in 1860-61 in Australia (Steinhart et al,1995). An Australian fern (*Marsilea drummondii*) with high levels of thiaminase was the cause of the death of the explorers. Aboriginal people in Australia prepared the fern sporocarps by grinding them with water to make a flour paste which could then be made into bread or eaten in a soup. However, the expedition members failed to realize the importance of this method of preparation and did not leach out or inactivate the thiaminase in the fern before consumption. The expedition members became progressively weaker, developed muscle wasting and eventually died of beriberi.

Heat-stable thiamine antagonists occur in several plants; ferns, tea, betel nut. They include *polyphenols*; these and related compounds are found in blueberries, red currants, red beets, brussel sprouts, red cabbage, betel nuts, coffee and tea (Hilker and Somogyi, 1982). They react with thiamine to yield the non-absorbable thiamine disulfide. In addition, some *flavonoids* have been reported to antagonize thiamine as well as *haemin* in animal tissues. (See Table 15).

Some bacteria (e.g. *Bacillus thiamineolyticus*) are also capable of destroying thiamine. It has been reported that 3% of Japanese show a thiamine deficiency due to this cause. Thiaminase bacteria have been frequently isolated from human stools in Japan and it was reported that the thiamine levels in the blood of these patients was low in spite of adequate intake largely due to the destruction of thiamine in the intestines (Bhuvaneswaran and Sreenivasan, 1962).

In Thailand, biochemical thiamine deficiency was reported to be common in the northern and north eastern provinces. Approximately 25% of the subjects studied were found to be deficient, i.e. TPP effect > 20% (Vimokesant et al,1975) and showed signs of extremity numbness, anorexia, weakness and aching of calf muscles. In the northern provinces about 80% of the adults chewed fermented tea leaves as a stimulant while betel nut chewing was common in other areas. In the north eastern provinces, fermented fish was eaten daily. A study undertaken by Vimokesant and others (1975) showed that the abstention from both betel nut chewing and raw fermented fish consumption resulted in a significant reduction of the TPP effect. The TPP effect again increased significantly when the subjects resumed their chewing habits Cooking of fermented fish

Table 15. Types of anti-thiamine factors and their actions

Anti-thiamine factor	Mechanism	Source
Thiaminase [1]		
Type I	alters the structure of thiamine	raw or fermented fish, shellfish, ferns, some bacteria
Type II	reduces biological activity of thiamine	certain bacteria
Thiamine antagonists [2]		
polyphenols (e g. caffeic acid, chlorogenic acid, tannic acid)	interferes with absorption or digestion of thiamine	tea, coffee, betel nuts, red cabbage, blueberries, red currants, red beets , also in cereals, pulses, oilseeds
flavonoids (e.g. quercetin, rutin)	"	widely distributed in edible fruits and vegetables, buckwheat plants
haemin	"	animal tissues

[1] heat labile enzyme
[2] heat stable non-enzymatic factors

destroyed thiaminase and resulted in a significant decrease of the TPP effect. Thiamine supplementation (10 mg/day) further decreased the TPP effect and could counteract the effect of raw fermented fish consumption but was not sufficient to neutralize the effect of betel nut chewing The habitual diet of the people studied provided for the RDA for thiamine (1.0 mg/day) thus suggesting that the regular consumption of natural anti-thiamine substances can lead to a biochemical thiamine deficiency even in the presence of adequate dietary thiamine intakes.

Another cause of thiamine deficiency in Thailand was reported to be tea drinking and chewing of fermented tea leaves ; tannins being the major component having anti-thiamine activity (Hilker et al,1971). A study by Kositawattanakul and colleagues (1977) found that ascorbic acid (vitamin C) protected the modification of thiamine by tea extract, not only at acidic pH, but also at neutral pH. High concentrations of Ca^{2+} and Mg^{2+} present in water were also reported by Vimokesant and others (1982) to augment the precipitation of thiamine by tannins. The precipitate formation makes thiamine less available for absorption by the intestine. Again, ascorbic acid, tartaric acid, and citric acid, all present in many vegetables and fruits, are said to lower such precipitation and increase thiamine bioavailability.

The following recommendations were made to decrease the influence of anti-thiamine factors in reducing thiamine absorption (Vimokesant et al. (1982):

- delay the consumption of tea or other tannin-containing products after a meal;
- consume foods high in ascorbic acid along with the meals;
- heat products containing thiaminase before consumption.

Strategies to prevent thiamine deficiency in large populations affected by emergencies

Background

In general, the most effective way to prevent micronutrient deficiencies, including thiamine deficiency, is to consume a diet containing a variety of foods, including fresh foods Emergency food rations usually consist of a cereal staple, pulses and oil. If the staple distributed is polished rice, highly milled wheat flour, or cassava/tubers the thiamine content of the ration is very low. Populations depending entirely on such a limited range of foods run the risk of developing thiamine deficiency even if their energy intake is adequate. An analysis of 24-hour food intake surveys carried out among Karen refugees in Thailand where thiamine deficiency was encountered (MSF/Epicentre, 1992) showed that just over 2 000 kcal were consumed: 83% was carbohydrates, 11% proteins and 6% was fat. The main cereal consumed was polished rice and the daily thiamine intake was 0 75 mg which is below the minimum RDA of 1 mg.

Main approaches

The main approaches to preventing thiamine deficiency in emergency situations affecting large populations are as follows:

- Providing food rations containing adequate amounts of thiamine by increasing the variety of the food basket and regularly including adequate amounts of legumes and vegetables.
- Providing parboiled rice or undermilled rice or other undermilled cereals instead of polished rice or other highly milled cereals.
- Fortifying current relief commodities with thiamine, e.g. providing fortified blended cereal-legume food in the general ration in sufficient amounts to cover thiamine requirements.
- Providing sufficient food in the ration to allow refugees to trade for a more varied diet.
- Providing thiamine (vitamin B-complex) supplements in the form of tablets.

Several of these options have been tried in various refugee settings with varying degrees of success The advantages and disadvantages of some approaches are discussed below.

Diversification of diet

Legumes (pulses, beans and groundnuts) are a good source of thiamine and should be part of the food basket of the affected population. Locally accepted types of legumes should be distributed to ensure that they are consumed Lentils distributed in the ration were the most commonly exchanged items among the refugees in Nepal since the distributed lentils were not the customary type used by the refugees in their homeland (SCF(UK) report, 1994)

Vegetables are also a source of thiamine and of other micronutrients and where feasible should be distributed as part of the general ration.

As a longer term strategy, diversification should be promoted by supporting vegetable cultivation as a routine component of all emergency-affected population assistance programmes. Nutrition education to promote the consumption of appropriate foods is an important component of any strategy.

Distribution of parboiled rice or undermilled rice in place of polished rice

The benefits of parboiled rice besides being a richer source of thiamine than polished rice have been mentioned earlier. In areas where rice is the staple food attempts should be made to introduce the parboiled variety. The organoleptic qualities of parboiled rice can vary greatly from polished white rice and a strong education programme is vital for the success of such an intervention. The experience in the Bhutanese refugee camp in Nepal showed that the quality control of parboiled rice was very important in order to ensure the distribution of a uniform quality of the rice.

Depending on the degree of milling, undermilled rice can have quite a high thiamine content. The main disadvantage of undermilled rice is the difficulty in keeping the quality of the product. The storage losses of thiamine in undermilled rice can be high. Undermilling also does not give the colour or cooking quality required by many consumers and it is very difficult to introduce it in areas where white polished rice is preferred.

Addition of thiamine-rich commodity to the food basket

When the general ration foods do not contain adequate natural sources of micronutrients, fortified legume-cereal blends have been added to the general ration of emergency-affected populations to cover their requirements for the various micronutrients. Research carried out by OXFAM/UNHCR (Mears and Young, 1998), looked at the usage of blended foods in an emergency at the household level In addition to investigating refugee preferences for a range of ration and non-ration foods, this study looked at the feasibility of cereal fortification in a refugee situation. There were no major problems with either the use or acceptability of blended foods. The study. however, highlighted some technical and operational issues regarding quality control and timely supply of locally produced food products. The strategy of cereal fortification clearly involves major issues of technical and operational feasibility in Africa which need to be dealt with for successful implementation of the use of fortified blended cereal foods. The disadvantages of using a special food originally designed for the supplementary feeding of malnourished children, which include. costs, shortage of the item, dependency on non-local product, have been discussed by Beaton (1995), by the Refugee Policy Group (1997) and by others (Toole, 1992)

Corn-soya-blend (CSB) provided by manufacturers in the US and Europe contains approximately 0.6–0.8 mg of thiamine per 100 g. The inclusion of 60 g of CSB to the general ration would bring the thiamine content of the ration to 1.1 mg which would cover the RDA for thiamine (0.9 mg for a mixed population). However, field studies would have to look at the preparation and cooking losses which have not been calculated in the above figure Currently not more than 30 g of cereal-legume blend per day is distributed in the ration which clearly does not provide for the daily requirement for thiamine if this is the only major source of the vitamin (see Table 2, for the thiamine content of a rice-based ration).

Biscuits are another food vehicle suitable for fortification with thiamine and have been distributed in several emergency-affected situations since they are ready to be consumed, need no preparation or cooking and are usually consumed by all members of the family.

Supplementation with thiamine/vitamin tablets

Regular thiamine or vitamin B-complex tablet supplementation is logistically difficult in large populations affected by emergencies. Thiamine or vitamin B-complex tablets need to be given daily; this is difficult to organize, expensive, and may be ineffective in the long term. Routine supplementation is recommended only as a means to treat outbreaks of the deficiency disease. However, vitamin B-complex tablets can be distributed to pregnant and lactating women via antenatal and postnatal clinics as a preventive measure.

Additional approaches

Reduction of losses of thiamine during preparation and cooking of meal

The losses of thiamine during the preparation and cooking of rice can be greatly reduced by:

- *Reduction of the number of washes of the rice before cooking*
  Most rice-eating communities wash the rice grains before cooking the rice. A survey carried out among refugees in Thailand reported that just over 75% of the cases surveyed washed the rice twice and over 12% washed the rice three times before cooking it (MSF/Epicentre, 1992). Washing the rice grains with large quantities of water leaches out a large percentage of the thiamine present.

- *Cooking of rice in two volumes of water only*
  Usually rice is cooked in a large quantity of water which is thrown away after the rice has been cooked. If rice is cooked in two volumes of water there is usually no water left after the cooking period. In any case the cooking water should not be discarded and can be used as a beverage and in the preparation of other foods.

The cooking losses of thiamine in vegetables can be reduced by:

- washing of vegetables before cutting them into small pieces;
- reducing cooking time to a minimum;
- immediate consumption of freshly prepared meal;
- cooking vegetables in minimum amount of water and consuming the water.

Reduction of the intake of anti-thiamine factors

Anti-thiamine factors are present in tea and in betel nuts and can have a direct influence on the development of thiamine deficiency especially in populations where thiamine intake is already marginal. Nutrition education and information campaigns are necessary to modify the food habits in such a population where the reduction of the intake of anti-thiamine factors can make a difference in the thiamine nutriture of the people.

Fortification of appropriate food item with thiamine

Staple foods poor in thiamine such as polished rice or milled cereals can be enriched with thiamine. The technology for the fortification of **milled rice** was developed in the USA in the 1940s. The method consists of fortifying grains of ordinary, milled, white rice with a high concentration of the desired supplementary nutrients i.e. thiamine, to produce a premix. The premix is covered by a film-forming, water insoluble coating that easily disperses during cooking. The premix is added to the raw polished rice and cannot easily be distinguished once it is added. Technically this fortification process is viable and economically advantageous since only 1-2% of the rice requires special processing. However, rice fortified in this way has not been acceptable because of the washing losses which range from 10 to 20%. More recently a new premix method has been developed based on the manufacture of synthetic rice kernels incorporating micronutrients like thiamine The rice kernel premix is added to normal white rice at the rate of e.g. 1 : 200 to provide the appropriate level of nutrients in the fortified rice. During cooking the nutrients are released from the premix kernels and are evenly distributed throughout the product. (WHO, 1976; USAID, 1993)

An alternative method for the fortification of milled rice developed in Japan was reported by Bhuvaneswaran and Sreenivasan (1962). It consisted of using dibenzoyl thiamine, a derivative of thiamine soluble only with difficulty in water but readily absorbed from the intestines and subsequently physiologically available to the body The premix was known as 'vitarice' and was available at a cheap price in shops in Japan, and the premix was usually added to the milled rice at the household level.

Wheat flour is a suitable food vehicle for fortification with thiamine. Fortification of white flour with a premix containing thiamine in addition to niacin, riboflavin and iron is carried out in many developed countries. The stability of thiamine in the fortified flour was reported as being very good with only 5% of thiamine lost after a storage period of 6 months. Bread baked with fortified flour retains its thiamine activity (USAID, 1993)

Corn meal can also be successfully fortified with thiamine and trials have shown no loss of the vitamin after 6 months storage of the fortified meal.

From a technical stand point **salt** can also be fortified with thiamine but no trials have yet been undertaken to look at the cooking losses of thiamine in fortified salt

Conclusions and recommendations

Populations affected by emergencies and dependent on food aid where milled rice is the major cereal distributed, and those dependent on starchy staple foods such as processed cassava and sago with few possibilities of diversifying their diets, usually have a low intake of thiamine even if their energy intake is adequate. A diet based on polished rice or any highly milled cereal, is high in carbohydrates which augments the thiamine requirement and is compounded by a low thiamine content. Thiamine deficiency can develop within 12 weeks of a deficient intake.

Although frank thiamine deficiency in non-emergency affected populations is rare today, large segments of the world's population continue to subsist on marginal or sub-marginal intakes of thiamine. People exposed to subclinical thiamine deficiency are predisposed to manifest frank beriberi under appropriate circumstances.

Nearly all living tissues contain thiamine and some thiamine is therefore derived from almost all foods. It is only with refined cereals i.e. white flour, white rice, degerminated maize meal, cereal starches, cassava and sago, as well as in products made from them, that the thiamine content is too low to support human life. Thiamine losses from cereals could be reduced drastically if flours of higher extraction rates are used. Rice would retain more thiamine if it were not highly milled; or if it was parboiled before milling. However, thiamine is water soluble and susceptible to destruction by several factors including: heat; oxidizing and reducing agents; neutral and alkaline conditions Losses that occur during the preparation of food can be minimized by improving preparation and cooking methods. In addition, thiamine in foods can be destroyed by anti-thiamine compounds that occur in foods.

It is difficult to speak of specific clinical symptoms of thiamine deficiency because of the variations of the clinical signs brought about by the presence of complicating factors, such as infections, or by the presence of symptoms from multiple deficiencies such as other B vitamins, vitamin C and minerals as well as the effects of stresses, such as physical labour and pregnancy. The clinical picture of frank thiamine deficiency in adults is, however, usually divided into a dry (neuritic) type and a wet (cardiac) type. The disease manifests itself principally with changes involving the nervous system, the cardiovascular system, and also the gastrointestinal tract. If untreated thiamine deficiency leads to death Thiamine deficiency in infants (infantile beriberi) is an acute disease that mainly affects infants breast-fed by women having deficient thiamine levels. The onset of the symptoms is often very rapid and the fatality rate is very high. Infantile beriberi must be suspected in a population if there is a high incidence of death in the first five months of life, particularly months 2-4.

Even a single case of clinical thiamine deficiency seen in a population reflects a public health problem and calls for a full nutritional assessment using biochemical methods to assess the thiamine deficiency where feasible.

Not all interventions to prevent thiamine deficiency are feasible in every emergency setting. The principle way of addressing thiamine deficiency is by improving the diet. Securing an adequate diet for large emergency-affected populations where polished rice is the staple can be a problem especially in the initial phase of a relief operation Distribution of parboiled rice where it is accepted would be one of the ways to help address the problem Table 16 summarizes several of the options for interventions to prevent or control thiamine deficiency during an emergency.

Primary strategies

The following approaches need to be considered to improve the thiamine content of a ration where natural sources of thiamine are available:

- Provision of adequate quantity of legumes (pulses) and vegetables. Legumes represent one of the most feasible options to provide for adequate thiamine intakes where polished rice is the staple. Fresh vegetables are also a source of thiamine and of other micronutrients and should be distributed as part of the general ration where feasible, if not readily home-grown.

Table 16. Options for the prevention of thiamine deficiency in an emergency

A. Natural sources of thiamine available locally

Natural sources available immediately

1. Provide adequate amounts of legumes and vegetables
2. Provide parboiled rice or lightly milled rice instead of polished rice
3. Provide lightly milled cereals (wheat, maize)
4. Encourage barter or purchase by providing 10% extra ration

Natural sources not available immediately

5. Encourage household food production of legumes, coarse grains (maize, millet), vegetables by providing necessary inputs

B. Natural sources not available locally

Provision of commodities fortified with thiamine

3. Provide fortified cereal-legume blends in the general ration
4. Provide fortified cereals in the general ration

Provision of thiamine supplements

5. Provide thiamine (vitamin B-complex) supplements

- Provision of parboiled rice instead of polished rice. Parboiled rice is a richer source of thiamine than polished rice and in areas where rice is the staple food attempts should be made to introduce the parboiled variety.
- Provision of lightly milled cereals (rice, wheat, maize) instead of highly milled ones. Lightly milled cereals are good sources of thiamine and should therefore be distributed where feasible, i e. where availability, acceptance and storage problems can be overcome.
- Provision of extra quantity of ration to encourage barter and/or purchase. Sale and/or barter of a portion of the ration should be encouraged where markets are available to enable the emergency-affected population to diversify their diet and thereby help cover their micronutrient needs.

The following approach of distributing fortified commodities needs to be considered to support the other interventions or as an alternative if the other interventions are not feasible:

- Provision of fortified cereal-legume blends The inclusion of 60 g of CSB to the general ration would cover the requirements for thiamine without considering preparation and cooking losses

- Provision of fortified cereals. Milled rice, wheat flour and corn meal can be fortified with thiamine However, the logistics and feasibility of cereal fortification at distribution sites and the retention of the vitamin during storage, distribution and meal-preparation needs to be assessed.

In situations where a population is at high risk of thiamine deficiency or where cases of thiamine deficiency have already been identified and all the other options for intervention are not immediately feasible, the following alternative needs to be considered:

- Supplementation with thiamine (vitamin B-complex) tablets. Routine daily supplementation is only recommended as a means to treat outbreaks of the deficiency disease. However, as a preventive measure vitamin B-complex tablets can be distributed to pregnant and lactating women via antenatal and postnatal clinics.

The interventions to prevent thiamine deficiency have to be adapted to the phase of an emergency feeding operation into short-term and longer-term solutions. The initiation phase may involve fortified food aid commodities, parboiled rice, or possibly locally procured legumes, vegetables and coarse grains, or where feasible an increase of the general ration by 10%. Promotion of home gardens as well as promotion of local trading and, where feasible, local milling to produce lightly milled cereals may be options during the establishment phase of an operation. Longer-term solutions to prevent thiamine deficiency should always aim at the self-sufficiency of emergency-affected households which includes local production of vegetables as well as local trading.

Supporting strategies

- ***Nutrition education***. Nutrition education should be seen as an essential component of any intervention to prevent thiamine deficiency Information, education and communication programmes that convey important messages can be inexpensive and achieve impact. The most efficient and durable interventions involve communication to educate and thereby modify consumption-related attitudes and practices. Messages to refugees can be vital in helping them to learn about their new environment, about different local foods that could be produced or purchased, and help in introducing unfamiliar imported food aid. Messages on how to reduce losses of thiamine during preparation and cooking of e.g. rice (see section 'Reduction of losses of thiamine during preparation and cooking of meal') could help in preventing thiamine deficiency. Nutrition education and information campaigns on the disadvantages of the intake of thiaminase and thiamine antagonists (e.g. raw fish, betel nuts, tea, coffee) would help to modify the food habits in a population where the reduction of the intake of anti-thiamine factors could make a difference in the thiamine status of the people

- ***Training of field workers***. Improving the skills of field workers in the clinical assessment and management of thiamine deficiency through training is essential for an intervention to be effective. It is also necessary to develop their capacity to analyze options and take appropriate action for the prevention of thiamine deficiency in emergency-affected populations where there is a likelihood of an outbreak or risk of thiamine deficiency.

- ***Establishment or identification of facility for biochemical assessment of thiamine deficiency***. Currently there are no field-friendly methods available for the biochemical assessment of thiamine deficiency. It is therefore necessary to identify facilities at the national level, or in a neighbouring country, where the thiamine status can be determined rapidly and with precision. Methods for the biochemical assessment of thiamine deficiency are summarized in the section 'Biochemical detection of thiamine deficiency'.

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