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SCURVY

and its prevention and control in major emergencies

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Scurvy

A disease caused by prolonged severe dietary deficiency of ascorbic acid, in which the breakdown of intercellular cement substances leads to capillary haemorrhages and defective growth of fibroblasts, osteoblasts, and odontoblasts results in impaired synthesis of collagen, osteoid, and dentine; it is characterized by haemorrhagic gingivitis affecting especially the interdental papillae (in the absence of teeth, the gums are normal), subperiosteal haemorrhages, bone lesions (including the corner fraction sign, a ground-glass appearance, and trabecular atrophy) seen on radiography, perifollicular haemorrhages, and frequently petechial haemorrhages (especially on the feet). Sudden death may occur as a result of cerebral or myocardial haemorrhage. Megaloblastic anaemia, usually due to concomitant iron and/or folate deficiency, is usual. The early manifestations include weakness, lethargy, myalgia, and arthralgia. In the infantile form (in which onset usually occurs in the second 6 months of life), gingival involvement is minimal and the infant assumes a ‘frog-like’ position and does not move its legs (owing to the intense pain of subperiosteal haemorrhages). In the adult form there are intraarticular and intramuscular haemorrhages, and osteoporosis may occur. The disorder may occur in infants born to mothers who are consuming large doses of ascorbic acid, and in adults following the abrupt discontinuation of large supplemental doses (despite relatively normal dietary intake of ascorbic acid).

Source: *International nomenclature of diseases.* Vol. IV Metabolic, nutritional, and endocrine disorders. Geneva, World Health Organization, 1991, p. 283.

Introduction

Scope

Although this document is intended primarily as a backdrop for interventions involving refugees, it is also suitable as a guide for ensuring adequate vitamin C intake in most emergency settings. It reviews the strategies and past experiences of the prevention of scurvy in refugee situations, and analyses factors influencing their success or failure. It reviews the constraints to the adoption of the recommendations. Innovative ways of improving vitamin C intakes are recommended and interventions are proposed for field-testing. Also included are a literature review of the epidemiology of scurvy and its signs and symptoms, the properties and functions of vitamin C, and a discussion of food sources of this vitamin and its stability. The recommended daily allowance (RDA) for vitamin C, including “minimum” as distinct from “optimum” intakes, is also discussed.

Background

Outbreaks of scurvy, hitherto a relatively rare micronutrient deficiency disease, have increased in frequency during the last decade among refugees dependent on food aid. In 1982, an outbreak of scurvy was reported among Ethiopian refugees in Somalia (Magan et al., 1983). Outbreaks of scurvy have also occurred in Sudan (1984, 1991), Somalia (1985), Ethiopia (1989), Nepal (1992) and Kenya (1994). During a workshop on improving the nutrition of refugees and displaced people in Africa held in Machakos, Kenya in December 1994, a number of recommendations were made for the prevention and control of micronutrient deficiencies during both the emergency and protracted phases of refugee operations. Blended foods (cereal-pulse blends) have been given in recent refugee emergencies, although little is known about their actual use. Nevertheless, the inclusion of fortified blended foods in the general food ration was recommended as the most feasible approach during the emergency phase (the first 6-12 months). For the protracted phase of an operation, local availability of fresh foods, ration exchange, employment opportunities, and food production possibilities were recommended. Research into the possibility of providing vitamin C by distributing dried chili peppers, sweets, reconstituted drinks, and seeds was also recommended.

Recent outbreaks of scurvy

Except for infantile scurvy, which was a well-recognised public health problem during the period 1945-65, particularly in Canada (Severs et al., 1961) and Australia (Turner et al., 1959), scurvy has been an extremely rare disease since the late 1940s. The problem was confined to infants that were not breast-fed and whose substitute food—most commonly evaporated cow’s milk contained little vitamin C. Scurvy was also reported in selected communities in South Africa, e.g. among mine labourers and chronically malnourished urban populations (Grusin & Kincaid-Smith, 1954) whose diet consisted mainly of maize porridge, bread, small quantities of meat, and vegetables which were usually so overcooked that they were virtually devoid of vitamin C. More recently, scurvy has been reported in groups consuming a monotonous diet, e.g. soldiers and prisoners (Mardel et al., 1995), and among alcoholics, people on fad diets (Sherlock & Rothschild, 1967), widowers living alone and unaccustomed to cooking (Reuler et al., 1985), and even hospital patients.

The most recent epidemic occurred in 1982 among Ethiopian refugees in Somalia as a result of problems associated with providing an adequate diet for a large population in inaccessible areas where local food supplies were limited. Magan et al., (1983) reported that the most prominent symptoms were pain in the joints of the lower extremities and bleeding gums. Most of those affected were pastoral nomads whose main traditional source of vitamin C was camel's milk. This population's total dependency on donated rations inadequate in vitamin C, and with no access to local markets, resulted in a high prevalence of clinical signs of vitamin C deficiency. Table 1 summarises the daily ration supplied to this group.

Table 1. Daily rations supplied to Ethiopian refugees in Somalia in 1982

	Amount (g)	Vitamin C content (mg)
Maize/sorghum	300	-
Wheat flour	75	-
Oil	30	-
Dried skimmed milk	40	2.8
Beans	40	-

Source: USAID, 1993

The daily requirement of vitamin C is estimated at 30 mg (FAO/WHO, 1970), although much lower daily doses of 6.5–10 mg have been found to be sufficient to prevent scurvy (G.B. Medical Research Council, 1953, Hodges et al., 1969, Hodges et al., 1971, Irwin & Hutchins, 1976).

With a diet completely lacking in vitamin C, body stores of vitamin C will last only about 2–3 months (Hodges et al., 1969; Carpenter, 1986). Although the refugees involved in the outbreak in Somalia had been in the camps for as long as 3 years, they had been supplementing their general rations with food (e.g. camel's milk, tomatoes, onions, sweet potatoes) purchased in the local markets in and around the camps (Magan et al., 1983). Six months prior to the scurvy outbreak, however, the Government of Somalia ordered the closure of all local markets. As a result poorer refugees were unable to purchase sufficient amounts of camel's milk or other vitamin C containing foods due to a sharp rise in price. Vitamin C tablets were distributed weekly to all refugees, and increased surveillance measures were instituted. More in-depth studies (of the interaction between socioeconomic factors and local food supplies) are required to explain the outbreak of scurvy in other camps not affected by the closure of markets.

Means of providing natural sources of vitamin C regularly to refugees are being explored but local sources are usually unable to deliver in required quantities. The importation of appropriate foods is costly and subject to the problems associated with transport and storage. Vitamin C is very unstable, easily oxidized, and destroyed by heat and sunlight (Marks, 1968). Since 1982, scurvy outbreaks have frequently been reported in other refugee areas, mainly in long-stay refugee camps on the Horn of Africa (Ethiopia, Kenya, Somalia and Sudan) where dwellers have not had access to fresh fruit and vegetables. Prevalence rates for scurvy in some camps for Ethiopian refugees have been among the highest recorded this century (see Table 2).

Desenclos et al., (1989) reported that in all camps cases of scurvy began to be reported within 3–10 months (median 4 months) of the refugees' arrival. The highest incidences occurred during and immediately after the dry season, February to May in Eastern Sudan and July to October in Northern Somalia. The risk of developing scurvy increased with the length of time that refugees had been in the camps and was higher among those who were older and among women of reproductive age. The prevalence of scurvy was similar irrespective of whether the refugees had participated in supplementary feeding programmes. Outbreaks occurred after 3–4 months consumption of relief food containing no more than 2 mg of vitamin C per day (WHO, 1989). No fresh food in significant quantities was available for purchase. Depending on the camp, vitamin C tablets, fresh food (lemons, onions) and/or corn soya milk (CSM) powder (40 mg vitamin C per 100 g (UNHCR, 1986)) were distributed.

Table 2. Prevalence rates of scurvy among refugees in the Horn of Africa

Year	Location	Population	Prevalence (%)
1982[a]	Southern Somalia	150 000	1–5
1984[b]	Eastern Sudan	50 000	22
1985[c]	North-West Somalia	160 000	7–44
1989[c]	Hartisheik Ethiopia	170 000	1–2
1991[d]	Kassala Sudan	20 000	15

[a] Magan et al. 1982; [b] Desenclos et al. 1989; [c] CDC, 1989; [d] Toole, 1992

Attendance at supplementary feeding centres and distribution of cooked rations prepared with CSM were not associated with any preventive effect. This may be due to the low concentration of vitamin C in CSM, and to the vitamin's poor heat and storage stability (Hallberg et al., 1982). The weekly distribution of vitamin C tablets to all children less than 5 years of age and to pregnant and lactating women, and the active enrolment of malnourished children in supplementary feeding programmes was instituted in June 1989 (Centers for Disease Control, 1989). Vitamin C tablets have only limited success because of problems with distribution and compliance. The only effective solution is to provide a complete general ration by distributing additional commodities or by fortifying existing ones (Seaman & Rivers, 1989). Mid- and long-term solutions need to be based on developing refugees' self-reliance through education campaigns and by encouraging home gardening efforts.

The extent to which scurvy contributes to mortality is uncertain. However, because vitamin C is associated with protection against infection and increased iron absorption (WHO, 1976), scurvy might well have had a role to play in the very high mortality and morbidity rates reported in the region (Toole et al., 1988). This underscores the need, and importance, of determining feasible interventions which will help to prevent vitamin C deficiency in refugee populations.

More recently, scurvy was reported at clinics in camps in Eastern Ethiopia with incidences as high as 3.5/1000/month in November 1993 and 12.8/1000/month in January 1994 (ACC/SCN, RNIS reports No. 3,4). Throughout 1993 food distribution to the camps was erratic and inadequate, there was little progress in developing self-sufficiency through rehabilitation programmes, and there were few opportunities for refugees to supplement their rations.

Persistent outbreaks of scurvy among Somali and Ethiopian refugees have occurred in Kenya; for example, there were reports of renewed outbreaks of scurvy in late 1994 (ACC/SCN, RNIS report No. 8). Shortages of fruit and vegetables in the markets because of drought, over-cooking of CSM, and seasonal factors affecting food availability were associated with the emergence of scurvy in Kenya (ACC/SCN, RNIS report No. 8).

In January 1994, the first cases of scurvy were reported among Bhutanese refugees in Nepal, mainly in the 10–30 year age group, with an incidence rate of 0.7/10000/day (ACC/SCN, RNIS Report No. 5). Throughout the first half of 1994, incidence rates were of the order of 0.5–0.7/10000/day. while in October 1995 the incidence was 0.12/10000/day (ACC/SCN, RNIS Report No. 13). Continued low levels of scurvy, despite inclusion of fresh vegetables and corn soya blend (CSB) in the general ration, suggests that entire households, or at least some members, lacked access to fresh vegetables and/or CSB, or had additional nutritional requirements.

Risk factors

The main risk factors for refugee populations are (Desenclos et al., 1989):

- Large refugee populations dependent entirely on external food aid for long periods.
- Absence of, or greatly reduced, access to a local market and/or no purchasing power to buy fresh fruits and vegetables or animal products (milk).
- Limited possibilities for growing vegetables due to scarce land and water resources.
- Overcrowded camps where infectious diseases spread quickly, thereby increasing vitamin C requirements.
- Increased risk among older persons and among women of reproductive age, especially if pregnant.
- The dry season, with the highest incidences of scurvy usually occurring during and immediately thereafter, e.g. as in Eastern Sudan and Northern Somalia.

Scurvy

Signs and symptoms

Classic scurvy

Vitamin C status follows the following stages (Hodges, 1980):

- The optimal stage with full saturation of the metabolic body pool.
- If the diet is less than optimal for some time, the metabolic body pool decreases in size, the person remains clinically well, and plasma levels remain within the normal range.
- If a deficient diet is consumed for a long enough period, the body pool is substantially depleted and plasma levels decline to the lower ranges of normal but with no clinical signs.
- The continuation of a deficient diet results in further decreases in the body pool size of vitamin C to 300 mg or less, a reduction in the catabolic rate to 9 mg or less, and the whole blood vitamin C content to a level below 0.3 mg/100 ml. Clinical signs of scurvy appear.

Manifest scurvy in adults is preceded by a period of latent scurvy whose early symptoms include lassitude, weakness and irritability; vague, dull aching pains in the muscles or joints of the legs and feet; and weight loss. Shortness of breath may also occur and the skin can become dry and rough. The principal signs and symptoms of manifest scurvy in adults consist of follicular hyperkeratosis, haemorrhagic manifestations, swollen joints, swollen bleeding gums, and peripheral oedema (Hodges et al., 1971). Anaemia of a variable degree occurs with scurvy in a certain percentage of adults and infants, which is considered to be due in part to undernutrition and intercurrent infection. However, it is due chiefly to the effect of vitamin C on blood formation, folic acid metabolism, and bleeding. In children the syndrome is called Moeller-Barlow disease, and is seen in non-breast-fed infants usually at about 5-6 months of age when maternally derived stores of vitamin C have been exhausted. No single symptom predominates, but the majority of infants with scurvy eventually show signs of irritability, tenderness of the legs, and pseudo paralysis, usually involving the lower extremities. The "pithed-frog" position—legs flexed at the knees and hips partially flexed—is assumed by approximately half the sufferers. Involvement of the costochondral junctions is very common, and costochondral beading is found in 80% of infants with scurvy. Haemorrhage around erupting teeth is consistently present. Petechial haemorrhages in the skin may occur (10 -15% of infants with scurvy). Left untreated, scurvy in any age group can lead to death.

Experimental scurvy

Several studies have been undertaken to determine the extent to which human scurvy, as seen clinically, can be explained purely by a deficiency of vitamin C in the diet. The English physician William Stark began a series of experiments on himself in the mid-1700s. During the first 12 weeks he lived on bread and water with a little sugar, at the end of which he was "dull and listless" with swollen gums that bled easily. For the next 3 weeks he consumed a more varied diet and recovered. Next, he returned to bread or flour with various supplements in turn—olive oil, butter, animal fat, a little cooked lean meat, and finally honey. He died about 6 months later, presumably of scurvy.

In 1939, John Crandon, a surgeon at Harvard Medical School, placed himself on a diet of bread, crackers, cheese, eggs, beer, pure chocolate, and sugar with supplements of yeast and all the known vitamins except vitamin C. From 6 weeks onwards no ascorbic acid could be detected in his blood plasma. After 12 weeks he began to feel fatigued. No clinical signs of deficiency developed until the 19th week when his skin became dry and rough and signs of hyperkeratosis began to appear. After 23 weeks small haemorrhages began to occur on his lower legs. He also had two self-inflicted wounds on his back. The first, made after 13 weeks on the diet, showed normal healing ten days later; while the second, made after 26 weeks, showed no sign of healing within ten days. Various tests showed rapid exhaustion. He was then given, by intravenous injection, 1 g of ascorbic acid each day for a week. A subjective improvement was noticed in the first 24 hours, and his second back wound healed rapidly within the following ten days.

During World War II an experiment was carried out in Sheffield, England, on volunteers who objected to military service. Their basic diet included milk, which was aerated for 30 minutes at 70°C with 1 ppm of copper added; and dried potato strips that were boiled in large volumes of water, left to stand in the water for 90 minutes, then mashed and kept hot for 30 minutes before being served. Daily vitamin C intake was less than 1 mg, although levels of other vitamins and iron were satisfactory (Hodges et al., 1971). After a variable period in which they received 50 mg supplementary ascorbic acid per day, ten of the volunteers received no more of the vitamin for 26–38 weeks. Ten others received either 10 mg or 70 mg per day. It took between 4 and 11 weeks for plasma levels of vitamin C to fall to undetectable levels. After 17 weeks, the subjects whose plasma level had fallen fastest showed some hyperkeratotic follicles on his upper arm; 4 weeks later, this was true of six of the ten subjects; and after 20 weeks in all ten, along with haemorrhaging in six. After 30 weeks without vitamin C, changes began to appear in the gums. By the 36th week, nine of the ten subjects had purplish, swollen, spongy and bleeding gums. After 26 weeks, wounds did not heal properly and subjects complained of pain and stiffness in their joints. In the 36th week, one subject, the day after heavy physical exercise, woke up with severe pain and difficult breathing. This was considered a cardiac attack due to scorbutic haemorrhage, which was also seen in another subject. Symptoms disappeared within 24 hours of receiving 1 g of vitamin C. The other members of the group were given a daily supplement of 10 mg vitamin C. All showed improvement after 2 weeks, their skin appeared normal after 8 weeks, and their gums were completely normal after 10-14 weeks. The group that received 10 mg vitamin C from the beginning of the trial developed no signs of deficiency, although vitamin C blood levels were at zero (Hodges et al., 1971).

Twenty years later another study was undertaken among prisoners in Iowa City, USA. For a hundred days, 4 male volunteers consumed a liquid purified diet composed of casein, sucrose, starch, oils, minerals, vitamins (other than C), and the amino acid cystine. The vitamin C content of the mixture was zero. Subjects were required to walk some 10 miles a day, and they maintained approximately constant weight on their 3000-calorie diet. Observations were similar to those seen in other studies except that signs appeared earlier—skin changes in 8–13 weeks and gum changes in 11–19 weeks. This was probably due to the fact that the diet contained absolutely no vitamin C. After 100 days, subjects were given doses of 6.5–34.5 mg vitamin C per day and all signs of scurvy disappeared (Hodges et al., 1969).

In 1953, the British Medical Research Council reviewed previous experimental studies and concluded that healthy men have stores of vitamin C sufficient to enable them to remain on deficient diets for periods ranging from 160–200 days without developing overt scurvy (Hodges et al., 1971). It was also stated that a daily dose of 10 mg of vitamin C was sufficient to prevent scurvy for as long as 424 days and that the same dose was enough to cure scurvy once it had appeared.

Experiments have shown that the onset of scurvy signals the development of serious consequences and that treatment should follow immediately. It is important to note that scurvy, as it appears today among refugees, is generally more severe and involves more systems than experimental scurvy. This is due to such factors as multiple deficiencies (e.g. anaemia), climatic extremes, a high level of physical activity, and associated infectious diseases. Otherwise, experimental and spontaneous scurvy are remarkably similar in clinical presentation.

Mild vitamin C deficiency

Mild vitamin C deficiency can be defined by plasma levels of less than 0.75 mg/dl and a total body vitamin C pool of less than 600 mg (Combs, 1992). The signs are lassitude, fatigue, anorexia, muscular weakness and increased susceptibility to infection. Epidemiological data also show increased risk of ischemic heart disease or hypertension (Combs, 1992). Marginal vitamin C deficiency can be caused by low dietary intakes as well as by factors like smoking, stress, chronic disease, and diabetes that increases the vitamin's turnover in the body.

Scurvy in pregnant and lactating women and infants

Pregnant women with low vitamin C intakes are not known to give birth to a scorbutic infants. Studies of breast-feeding women also indicate not only the freedom from scurvy in their infants, but also a larger amount of vitamin C in their milk than the women themselves consume daily. Secretion into milk seems to have high priority in maternal vitamin C economy; concentrations up to 48 times higher than in maternal plasma have been found in breast milk (Salmenpera, 1984). Infants had plasma concentrations 6–12 times higher than corresponding maternal concentrations. There is an obvious adaptive preventive effect against vitamin C deficiency even among infants whose mothers' nutrition is marginal (Salmenpera, 1984). No symptoms of scurvy have been known to appear in infants breast-fed by malnourished mothers with very low concentrations of vitamin C in their milk (Deodhar et al., 1964).

One study showed that the mean infant/maternal plasma concentration ratio was 2 during delivery and appeared to be similar or higher during lactation (Salmenpera, 1984). Surprisingly, infants' plasma concentration continued to rise despite the decreasing concentration of vitamin C in milk. This maintenance of high plasma concentration in infancy suggests that a high concentration is necessary during infant growth. The fetal brain is reported to contain a concentration of vitamin

C several times higher than the adult brain (Adlard et al., 1974). A study undertaken by Rajalakshmi et al. (1965) showed that pregnant women in India who were ingesting less than 10 mg of vitamin C per day were in fact secreting 15–30 mg of the vitamin in their milk while showing no clinical signs of scurvy. These findings suggest that the human breast and placenta might be able to synthesize some vitamin C (Hodges, 1980).

Diagnosis of scurvy

The main criteria for diagnosing scurvy are:

- A history of dietary inadequacy of vitamin C.
- Clinical manifestations characteristic of a scorbutic state (Tables 3 and 4).
- Biochemical indices, i.e. low levels of vitamin C in the blood (serum, white blood cells and whole blood) and a low urinary excretion rate.

The clinical picture of scurvy in children is quite different from that seen in adults, the impact on growing bones being one of its earliest and most prominent distinguishing features. In contrast to adult scurvy, haemorrhaging is less common among children during the early stages of the disease.

Biochemical evaluation of vitamin C status in humans is usually conducted through a determination of *serum (plasma) ascorbic acid* levels. Serum levels of ascorbic acid show a linear relationship with vitamin C intake. When deprived of vitamin C, a subject's concentration of plasma ascorbic acid decreases rapidly while, with a given intake of the vitamin, the plasma ascorbic acid concentration will plateau at a given level (Sauberlich et al., 1974). The maximum plasma ascorbic acid level appears to be about 1.4 mg/100 ml, at which point renal clearance of the vitamin rises abruptly. Although low plasma ascorbic acid levels do not necessarily indicate scurvy, clinical cases of scurvy always have low or no plasma ascorbic acid. However, continued low levels of plasma ascorbic acid of less than 0.1 mg/100 ml would probably eventually lead to scurvy (Hodges et al., 1971).

There is also a well-defined relationship between *whole blood ascorbic acid* values and the body reserves of the vitamin, with signs of scurvy appearing when the whole blood ascorbate level falls below 0.3 mg/100 ml (Hodges et al., 1969). Whole blood ascorbic acid levels are probably a less sensitive indicator of vitamin C nutriture than serum levels of the vitamin since the ascorbic acid levels in red blood cells never fall to the low levels encountered in serum or plasma (Sauberlich et al., 1974).

Table 3. Clinical manifestations of scurvy in adults

Body system	Typical lesion
Skin:	C Diffuse petechial haemorrhages* C Hyperkeratotic follicular papules** on the calves and buttocks with spiral unerupted hairs
Mouth:	C Bleeding gums C Loosening of teeth C Petechial haemorrhages*
Eye:	Intra-ocular haemorrhages
Blood:	Moderately severe anaemia
Bones:	C Irregular masses of calcified cartilage in fibrous tissue C Marrow spaces become filled with a loose connective tissue C Bone shafts become less dense

***** Small purplish red spots due to intradermal or submucous bleeding.
****** Thickening of the corneal layer or small elevations of the skin.

Table 4. Clinical manifestations of scurvy in infants and young children

Most frequent symptoms
- General irritability
- Tenderness of the limbs, especially of the legs
- Pseudo paralysis, usually involving the lower extremities
- Involvement of costochondral junctions: changes such as beading of ribs
- Haemorrhage around erupting teeth (in infants without teeth gums appear normal)
- Anaemia

Possible symptoms
- Anorexia
- Low-grade fever
- Mild diarrhoea, sometimes bloody
- Petechial haemorrhages in the skin

White blood cell ascorbic acid concentrations are more closely related to tissue stores of the vitamin than are serum levels. With vitamin C deprivation, white blood cell ascorbic acid levels fall more slowly than plasma ascorbic acid levels and are most pronounced in association with the onset of signs of scurvy (Sauberlich et al., 1974). However, because determination of ascorbic acid in white blood cells is technically difficult and requires relatively large blood samples, it is impractical for routine use in nutrition surveys.

Table 5 proposes cutoff points for mild, moderate and severe vitamin C deficiency based on ascorbic acid levels in whole blood, plasma and white blood cells. Table 6 suggests guidelines for differentiating among levels of risk for vitamin C deficiency in a population.

Table 5. Cutoff points for interpreting vitamin C biochemical data (all age groups)

	Deficient (high risk)	Low (medium risk)	Acceptable (low risk)
Serum ascorbic acid (mg/100 ml)	< 0.2	0.2 - 0.29	> 0.3
Leukocyte ascorbic acid* (nmol/10^8 cells)	< 57	57 – 114	> 114
Whole blood ascorbic acid (mg/100 ml)	< 0.3	0.3 – 0.49	> 0.5

Source: Sauberlich et al.,1974. * Data kindly updated by H.E.Sauberlich (1999)

Table 6. Provisional criteria for severity of public health problem of vitamin C deficiency

	Severity of public health problem		
Indicator	**Mild**	**Moderate**	**Severe**
Clinical signs:	$1 clinical case; <1% of population in age group concerned	1-4% of population in age group concerned	$5% of population in age group concerned
Serum ascorbic acid			
<0.2 mg/100ml	10-29 %	30-49 %	$50 %
<0.3 mg/100ml	30-49 %	50-69 %	$70 %

Derived from: Sauberlich et al., 1974, Desenclos JC et al., 1989.

History of scurvy

Outbreaks

> *A large number of men in our army were attacked also by a certain pestilence, against which the doctors could not find any remedy in their art. A sudden pain seized the feet and legs; immediately afterwards the gums and teeth were attacked by a sort of gangrene, and the patients could not eat any more. Then the bones of the legs became horribly black, and so, after the greatest patience, a large number of Christians went to rest on the bosom of the Lord.*
>
> Jacques de Vitry,
> 13th century.

Scurvy is one of the oldest diseases known to humankind. There is evidence of its existence in the Old Testament, the Ebero Papyrus, and the writings of Pliny (Marks, 1975). The first concise account of scurvy, written in the 13th century, appeared in Jacques de Vitry's history of the Crusades, which included travelling to the dry countries of Eastern Europe and Southern Asia where few green vegetables were available for the foreign travellers. Many fell ill with scurvy. In the Middle Ages scurvy was endemic in Northern Europe during the late winter months due to the unavailability of green and root vegetables. Europe was introduced to the potato in the late 16th century by explorers bringing tubers back from Central and South America; it began to be generally cultivated and eaten throughout Europe during the 18th century. By 1800, scurvy had disappeared from many parts of Scotland where it had previously been endemic. During the same period potatoes became a regular part of the diet. Scurvy reappeared in Europe during the Great Potato Famine (1845-1848) when potato crops were lost due to bad weather (Carpenter, 1986).

At the end of the Middle Ages, sailors began travelling farther away from Western Europe. The first outbreak of sea scurvy was recorded during the Portuguese expedition to India in 1497 led by Vasco da Gama. The expedition lasted 4 months and out of 148 crewmen 93 died, chiefly from scurvy (Watt, 1982). Thereafter, there were numerous reports of scurvy on voyages lasting longer than 90 days, with Dutch, English, French, Portuguese and Spanish expeditions all being affected. Many lost a large proportion of their crew due to lack of vitamin C in naval rations. McCord (1959) has argued that scurvy, which killed two million sailors between 1500 and 1800, should be classed as history's foremost occupational disease.

Another major outbreak of scurvy occurred in California between 1848 and 1850 (Lorenz, 1957). Gold was discovered in a remote part of northern California in 1848. Over the next two years, some 100 000 people set off from the East Coast, either by sea or overland, to the gold fields. The distance overland was some 2500 miles and the journey lasted more than 6 months. Typical provisions were similar to those taken for a long sea voyage, e.g. flour and biscuits, sugar and salt powder or beef. At certain places and times of the year berries could be picked. Generally speaking, however, vegetation was very sparse in the Rocky Mountains. It was reported that at least 10,000 men died of scurvy, outnumbering those dying from cholera (Lorenz, 1957).

The next large-scale outbreak of scurvy occurred during the Crimean War (1854-1856); the many thousands of cases were a major cause of the heavy losses sustained by both the Turkish and French armies (Carpenter, 1986). Other outbreaks were reported during the American Civil War (1861–1865) and the siege of Paris during the Franco-Prussian War (1870–1871). In all cases the cause was identical: an absence of vitamin C in the diet.

Expeditions to the Arctic (1850–1915) experienced scurvy, including the famous Scott and Amundsen expeditions to the South Pole that ended tragically, most probably due to scurvy. Food rations included pemmican, biscuits, butter, cocoa, sugar and tea, all of which lacked vitamin C.

Other major outbreaks of scurvy occurred among infants as a new "disease of affluence", especially during the period 1877–1917. The increased use of manufactured infant foods, which at the time were poor sources of vitamin C, was presumably the main reason why infantile scurvy became such a problem in relatively well-to-do families (Evans, 1983). In fact, infants in poor families showed no signs of scurvy since they were usually breast-fed and, later, given potatoes as a complementary food instead of more expensive farinaceous foods.

Treatment and prevention

Antiscorbutic foods

As far back as the 11th century seafarers were advised to take with them a supply of apples, peas, pomegranates, cucumbers, citrons, lemons, muscats and pickled vegetables (Watt, 1982). During the period 1740–1790, a great number of foods were recommended as supplements to the sailor's diet (see annex for the vitamin C content of some traditional antiscorbutics used in the 18th century). The benefits of lettuce and fresh vegetables were known, but these foods were too difficult to transport and store during long voyages. Onions were among the sources of vitamin C that sailors could take with them (Carpenter, 1986). Like other food sources, onions lose most of their vitamin C content when boiled, but in the 18th century sailors presumably ate them raw (Norris 1983). The Dutch were the first to recognize the antiscorbutic effect of oranges and lemons; they discovered it by accident after picking up cargoes of these fruits in Spain en route to Holland. Later, pinetops, scurvy grass, different cresses, coconuts, and guavas were also found to be effective antiscorbutics (Watt, 1982).

Berries were prized as being antiscorbutic in northern Europe, as were rose hips, which are a rich source of vitamin C. Potatoes played an important role as the major source of vitamin C in northern Europe in the 19th and 20th centuries, especially during the winter months when fruits and vegetables were not available. Potatoes are not as rich in vitamin C as some fruits and vegetables, but they were a cheap staple food eaten in quantity day after day. Even when cooked, a single serving can contribute 5–40 mg of vitamin C daily (Carpenter, 1986).

Germinated seeds and malt

The Dutch tried to establish vegetable gardens on their East Indies fleet but found it impracticable. During the end of the 18th century sprouted beans—a rich source of vitamin C—were recommended as an antiscorbutic, but malt (sprouted barley), after it had been dried and stored as a powder on board ship, was of minimal value. The use of malt soup, made by heating malt extract with milk, was associated with a high incidence of infantile scurvy. Beer was also repeatedly recommended as an antiscorbutic. Beer consumed immediately after the fermentation period, and not boiled before fermentation, might have been an effective antiscorbutic. However, beer produced commercially after 1850 was devoid of vitamin C (Watt, 1982).

Another drink prized by sailors since the 16th century was "spruce-beer" made from the green leaf buds of fir trees. Extracts made from leaves of the American spruce, the tree thought to have been used by the Canadian Indians who shared their remedy with Jacques Cartier on his voyage to Newfoundland in the 16th century, yielded 200 mg of vitamin C per 100 g of leaves (Carpenter, 1986). Although infusions of fresh spruce leaves contained 14 mg/100 ml, after fermentation the vitamin content virtually disappeared (Hughes, 1975). Cider, i.e. fermented apple juice, was also recommended, but depending on how it is made it contains little or no vitamin C.

In 1747, James Lind carried out his famous controlled clinical trial on board a British naval vessel to prove conclusively the power of lemons and oranges over popular remedies to cure matched scorbutic cases on a scorbutic diet. Twelve sailors with scurvy were divided into two-man teams, and each received a different antidote: cider, diluted sulfuric acid, vinegar, sea water, various drugs, or 2 oranges and a lemon a day. Those receiving the oranges and lemons improved after 6 days. Those receiving the cider were the next best at the end of 2 weeks. His conclusion was "that oranges and lemons were the most effective remedies for this distemper at sea" (Hughes, 1975).

The main problems with oranges and lemons were storage and transportation. The pressed juice was used as an antiscorbutic. After 1875, however, there was a loss of faith in lime juice in naval circles since most of the vitamin C was lost largely as a result of long periods in settling tanks and the pumping of juice through copper pipes (Carpenter, 1986). Evaporating 800 ml juice down to one-tenth of this volume to produce “robs of oranges/lemons” resulted in the loss of one-half of the vitamin. When the rob was stored for a month at room temperature, less than one-seventh of the original vitamin remained (Hughes, 1975).

There have been a number of theories about the cause of scurvy since the 18th century, e.g. food poisoning, infection, protein deficiency, and a deficiency of potassium and/or iron. These theories in turn were a reflection of the methods used to prevent and cure scurvy.

Inuit diets

One puzzle for 19th century students of scurvy, who believed in the special properties of fresh fruits and vegetables, was that despite lack of access to these foods Inuits normally remained scurvy free. Inuits eat large quantities of meat and fish in a raw, or only slightly cooked, state. A considerable amount of vitamin C is thereby contributed to the diet even if the average con-centration is relatively low (see annex for the vitamin C content of some traditional Inuit diets). Inuits have been reported to eat the raw liver of both seals and caribou, and even a small amount of such organ meat would satisfy a day’s requirement for the vitamin (Hoppner et al., 1978).

Vitamin C

Discovery

By the beginning of the 20th century, it was widely known that there was an antiscorbutic substance in certain fruits and vegetables that could prevent or cure scurvy. Since the terms “fat-soluble A” and “water-soluble B” had already been chosen, the antiscorbutic substance was named “vitamin C” (Hodges 1980). Many individuals attempted to discover the nature of the antiscorbutic substance and fortunately the guinea pig was selected as a suitable animal for studying vitamin C deficiency. Vitamin C is the only vitamin required in the human diet that is not required in the diets of most animal species except in that of primates, the guinea pig, the fruit-eating bat of India, a few other birds, and several species of trout and salmon (Combs, 1992).

Zilva worked for many years attempting to isolate and identify the antiscorbutic factor; he demonstrated that it was quite perishable under conditions of heat, aeration, and contact with metals such as iron and copper, and that it was water-soluble. Two other groups—King and Waugh and Szent-Gyorgyi (Hodges, 1980)—working independently isolated vitamin C almost simultaneously and both reported on it in 1932. Shortly after the joint discovery and identification of vitamin C as “hexuronic acid”, this compound was synthesised. Pure ascorbic acid is synthesized from d-sorbitol where 100 g of the sugar results in a yield of 30 g of ascorbic acid.

Properties

Chemistry

L-ascorbic acid, which is often equated with vitamin C (Marks, 1975), has much in common with its precursor, D-glucose. The empiric formula is $C_6H_8O_6$, and in its pure form it is a white odourless, crystalline substance with a melting point of 192ºC. It is a very powerful reducing agent, reducing silver nitrate, potassium permanganate, iodine, and many organic substances. It is freely soluble in water, slightly soluble in ethanol, and quite insoluble in most non-polar lipid solvents. In crystalline form, kept dry and not exposed to light, it is stable for a considerable length of time. In an aqueous solution it is attacked by atmospheric oxygen, other oxidizing agents, high pH, high temperature and metallic ions.

L-ascorbic acid is reversibly converted to dehydroascorbic acid, which together constitute the active form of vitamin C (Hodges, 1980). Dehydroascorbic acid can be oxidized further both rapidly and irreversibly at a pH above 4 where traces of heavy metal ions, e.g. copper, act as catalysts. The end products are oxalic acid and L-threonic acid.

Physiology

Vitamin C is readily absorbed from the gastrointestinal tract by an active transport mechanism, particularly at low intakes of the vitamin. Uptake by passive diffusion also occurs and is likely to be important at higher vitamin C intakes (Combs, 1992). A dose of less than 100 mg will be almost completely absorbed, whereas only about 70% of a dose of 180 mg is absorbed. When the dose is further increased to 1500 mg, only about half is absorbed, while at a level of 1.2g, only 16% is absorbed (see Table 7). The unabsorbed ascorbic acid remaining in the lumen of the bowel exerts an osmotic effect and can cause loose watery diarrhoea (Hodges, 1980). Absorption can be impaired in the aged and persons with excessive destruction or damage to the gastrointestinal tract.

Once L-ascorbic acid is absorbed, it is distributed throughout the body's water-soluble compartments. The metabolically active pool is approximately 1500 mg in healthy middle-aged men (Baker et al., 1971). In guinea pigs the concentration of this vitamin is highest in the adrenals, pancreas, salivary glands, testes, and brain (Hodges, 1980). There is no stable reserve of vitamin C; the major fractions are found in the liver and muscles by virtue of their relatively large mass (Combs, 1992). Excess of vitamin C is rapidly excreted largely in urine, but also to some extent in sweat and faeces. Thus, loss of vitamin C mainly occurs in the urine, which depend on body stores, intake and renal function (Marks, 1975). The first signs of scurvy are not seen until reserves are depleted to 300–400 mg.

A continuously low plasma vitamin C level (<0.1 mg/dl) can lead to scurvy. In humans, a plasma level of 0.4–1.4 mg/dl corresponds to a daily intake of 40 mg of vitamin C; with higher levels indicating saturation (Combs, 1992). Leucocyte vitamin C concentrations have a particular diagnostic value, as they reflect the levels found in tissues and are independent of plasma concentration. Leucocyte vitamin C concentrations are usually greater in women than men and decrease with age and some diseases (Combs, 1992). When body stores are depleted, administration of vitamin C results in storage until the tissues have been saturated, at which time urinary excretion increases. The difference between intake and excretion of the vitamin approximates the amount of vitamin utilized. The normal subject has been found to be capable of utilizing from 45 mg/day to 100 mg/day.

Metabolic functions

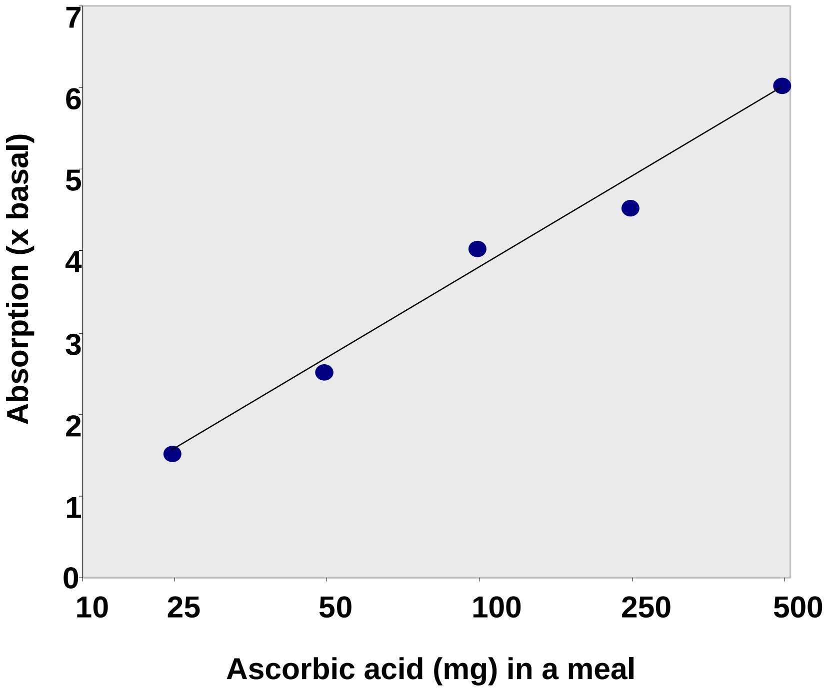
The most clearly defined function of vitamin C is to maintain collagen formation; it appears to serve as a coenzyme in the hydroxylation of proline to hydroxyproline, which is an important step in collagen synthesis (FAO/WHO, 1970). It is also involved in other hydroxylation reactions, although the specific mechanisms are not known. Clinical observations show that vitamin C may be necessary for the normal metabolism of tyrosine in both children and adults. Vitamin C is considered to be effective in healing wounds. Absence of vitamin C, particularly in newly formed tissue, is associated with marked impairment of collagen formation. Nevertheless, massive doses do not hasten wound healing. Vascular reactivity is abnormal in scorbutic conditions.

Studies of experimental scurvy show that the haemorrhagic phenomenon can appear even though all tests for blood clotting activity as well as biopsies of capillaries remain normal (Hodges et al., 1969). Vitamin C plays an important role in converting the vitamin folacin to folimin acid in connection with the manufacture of blood, in addition to regulating the respiratory cycle in the mitochondria and corpuscles. The evidence is unclear whether large amounts of vitamin C play a role in preventing infections and protecting against the effects of stress and detoxifying chemicals. Also, there is no reliable evidence that large doses of vitamin C protect against the common cold (Carpenter, 1986). However, evidence is accumulating that vitamin C has certain reasonably clearly defined metabolic functions other than the prevention of scurvy.

Vitamin C increases the bioavailability of both non-haem and haem iron in foods by increasing its absorption by 200–600% (see Fig. 1). The effect depends on the simultaneous presence of vitamin C and iron in the gut, e.g. the amount of vitamin C-containing food consumed with a meal and the amount of vitamin C ingested. Vitamin C can interact with several metallic elements of nutritional significance. Due to its activity as a reductant, vitamin C lowers the toxicity of elements whose reduced forms are poorly absorbed or more rapidly excreted, e.g. selenium, nickel, lead and cadmium (Combs, 1992).

High utilization rates for vitamin C have been found in many psychiatric patients and an improved mental state has been found in controlled trials with high doses of vitamin C (Marks, 1975). Vitamin C is involved in histamine metabolism. Blood histamine and vitamin C concentrations are negatively correlated in women in pre-term labour (Combs, 1992). Vitamin C has also been found to affect immune function in several different ways, e.g. stimulating the production of interferon (Combs, 1992). Other roles of vitamin C mentioned in the literature include as an anti-stress factor and as a necessary substance in the regulation of cholesterol. Many properties of vitamin C are related to its being an antioxidant and reacting rapidly with organic free radicals, which is an important feature of protecting living tissues against the detrimental effect of free radicals.

Figure 1: **Effect of increasing quantities of ascorbic acid on the absorption of non-haem iron in a meal**



Source: De Maeyer et al., 1989

Use of vitamin C

In addition to using synthetic vitamin C for direct supplementation, food manufacturers have used it for a variety of other purposes.

Bread-making

The usefulness of vitamin C in bread-making depends on its ability to modify the properties of wheat flour proteins in a technologically advantageous manner. As early as 1935, vitamin C was found to be as effective in improving flour as potassium bromate, while being nutritionally more acceptable. Flour improvers shorten the time required for flour to “age” after milling and the time that the mixture of dough and yeast requires for “ripening” before baking. Vitamin C acts as an oxidizing agent in the dough; it is oxidized to dehydroascorbic acid, which then participates in the oxidation of the wheat protein, gluten, to form cross-linkages. These stages are vital for a loaf to rise well and keep its texture after leaving the oven. There was considerable interest in flour improvers (Chamberlain, 1981) since, in order for bread to be mass-produced economically, it was necessary to shorten the production stages.

Meat processing

Treating fresh meat with a vitamin C solution delays the change of the fresh red appearance of meat to a less fresh-looking brown. This use is prohibited in some countries, e.g. the UK, as being “deceptive to the public”, though it was claimed that the same result could be obtained by feeding animals a high level of vitamin C before slaughter. The vitamin is used in fresh sausages and as an additive in cured products (Ranken, 1981). The reason for curing meats is that they can then be stored, even without refrigeration, with little risk of infection by the highly pathogenic organisms of the Botulinus family in addition to developing an attractive characteristic pink colour. The traditional curing of meat involves pickling with a solution of salt and potassium nitrite. Since nitrosamines, which can be carcinogenic at very low concentrations, can be formed by nitrites, the food industry was under pressure to find ways of curing meat with lower nitrite levels. Vitamin C was found to be a useful additive for developing an attractive colour in cured meats having a lower nitrite content (Ranken, 1981).

Fruit juices and beverages

Fruits are an important source of vitamin C and fruit juices are a major contributor to vitamin C intake in Europe and North America. Vitamin C is often included in soft drink formulations, which serves to stabilize their quality, especially where colour and flavour are concerned. In certain instances the vitamin serves as an important processing acid, e.g. for removing oxygen from solutions in order to increase product shelf-life.

Oils and fats

Vitamin C is used as an antioxidant in oils and fats. Antioxidants prevent or retard oxidation, in particular the oxidative rancidity caused by atmospheric oxygen, and thus protect fats, carotenoids, vitamins A and D, and other nutritive ingredients. Many factors influence the antioxidant effectiveness of vitamin C, e.g. the specific content of metals, oxygen, and polyunsaturated lipids. In each case optimum vitamin C treatment has to be determined, in addition to the effects of physical conditions, packaging, water activity, etc. (Kläui,1979).

Vitamin C, which is itself insoluble in lipids, is added to oils and fats as ascorbyl palmitate (AP). Unfortunately, AP has a very slow dissolution rate in oils and fats at room temperature and in the end very little dissolves. AP is thus usually used in combination with products acting as solubilisers, but even then a fair dissolution rate is achieved only at high temperatures (Kläui, 1979). Efforts to overcome these drawbacks led to the development of a special application form where AP is pre-dissolved in lecithin, thus making it significantly easier to dissolve in lipid systems. Two commercial antioxidant mixtures containing BHA (butylated hydroxy anisole) and BHT (butylated hydroxy toluene)—but rarely AP—are added to vegetable oils (P. Ryffel, Roche, personal communication).

It has been suggested that since dehydroascorbic acid is more fat-soluble than ascorbic acid, in addition to exhibiting biological vitamin C activity, it might show advantages in certain systems.

Food fortification

The fortification of food—the enrichment of commonly consumed foods with micronutrients in order to improve the nutritional quality of the diet—is increasingly used for novel food products that are marketed to replace traditional diets. The increasing use of refined foods in industrialized countries, and the introduction of engineered foods that are formulated from highly purified ingredients, can contribute to micronutrient deficiencies if not adequately upgraded, e.g. margarine with vitamins A and D and cereal products with vitamins B_1, B_2, niacin and iron.

Items regularly fortified with vitamin C in several countries, especially in Europe and North America, include various bottled beverages as well as instant drinks, milk, and baby foods. "Protein treats"—solid bars with a chocolate-like texture that are simpler to manufacture than chocolate, and various types of candy bars—can be enriched with vitamin C. All these products have a long shelf life and packing and transport present no special problems. Several types of biscuits, including simple biscuits or sandwich biscuits with a soft filling, are vitamin C-fortified. Vitamin C is more stable in biscuits with a soft filling but their shelf life is shorter (P. Ryffel, Roche, personal communication). Other products like dry instant soup mixes are relatively easy to manufacture, transport and prepare. Fortified instant soup mixes have been used for school children in the former Yugoslavia during the late winter and early spring months when dietary intakes of the vitamin were low. Vitamin C in the form of a premix has been added to meals during their preparation in kindergartens, schools, industrial canteens, hospitals, and homes for the elderly. In some of these same settings vitamin C powder has also been added to water before drinking (Buzina, personal communication).

Recommended Daily Allowance (RDA)

Problem of calculating RDA for vitamin C

The recommended daily allowances for most vitamins are remarkably similar from country to country and from year to year. However, this is not the case with vitamin C. The appropriate daily intake is still vigorously disputed by scientists, and recommended allowances not only vary from one country to another; they also change from time to time within the same country. Although everyone agrees that the minimal daily requirement for vitamin C is 10 mg or slightly less, there is little agreement regarding recommended intakes.

In the late 1930s, the League of Nations concluded that adult requirements are covered by 30 mg per day and that requirements increased during, and following, febrile conditions. In 1941, the U.S. National Research Council (NRC) issued its first edition of RDAs, which included 75 mg of vitamin C for an adult male since this resulted in tissue levels similar to those in the "synthesizing" species, e.g. guinea pigs. In 1974, the NRC issued a new set of recommendations where the adult allowance was reduced to 45 mg, on the understanding that this intake will maintain an adequate body pool of 1500 mg. In 1980, the NRC recommended a daily intake of 60 mg after estimating that only 85% of the ingested vitamin was absorbed into the bloodstream. Other RDAs (mean values for adult, moderately active, men) as of 1980, are found in Table 7.

There is some variation in the methods by which vitamin C status has been evaluated. The daily vitamin C requirement for saturation ranges from 50–77 mg when estimated from data on whole blood ascorbic acid levels, from 70–131 mg when plasma levels are being determined, and from 22–83 mg when white blood cell ascorbic acid levels are being assayed. An even wider range of 26–125 mg is observed when saturation is judged by urinary ascorbic acid excretion (Irwin & Hutchins, 1976).

Table 7. Recommended daily allowances for vitamin C

	mean vitamin C values (mg/day) for moderately active adult males
FAO/WHO (1970)	30
Australia, Canada, UK	30-40
Holland, India, Japan	50
Germany, Philippines, Switzerland	75
Russia	100

Studies with radio labelled ascorbic acid have shown that when doses of <100 mg of ascorbic acid are ingested by humans, the absorption efficiency may be as high as 98% (Olson & Hodges, 1987). When larger amounts are ingested, the absorption efficiency decreases to 70% at a dose of 180 mg, to 50% at 1500 mg, and to 16% at 12000 mg (see Table 8). Vitamin C absorption is increased significantly when given with food, perhaps because of a slowing of intestinal transit time. Thus, the absorption efficiency seems to be 90% or more over a range of 20-120 mg per day of usual intakes in food. Table 9 shows the daily intakes of vitamin C recommended by the joint FAO/WHO expert group (1970). It was stated that heavy physical activity may increase the need for vitamin C, but that there was no definite evidence for this.

Table 8. Absorption rates of vitamin C in relation to amounts ingested

Amount of vitamin C ingested (mg)	Absorption rate (%)
< 100	98
180	70
1500	50
12 000	16

Table 9. FAO/WHO recommended daily allowances for vitamin C

	Vitamin C (mg/day)
Infants (0–6 months)	Breast-feeding by a well-nourished mother
Infants (6–12 months)	20
Children > 13 years and adults	30
Pregnant women (2nd and 3rd trimester)	50
Lactating women	50

The recommended intake of 30 mg of vitamin C per day would be covered by half an orange or 50 ml of citrus fruit juice; by a good-sized tomato (30 g) or a small helping (50 g) of good quality leafy vegetables; or by a large helping (120 g) of potatoes, depending, of course, on the storage and cooking methods used (WHO, 1974).

RDA for adults

Olson and Hodges (1987) have suggested 40 mg daily as the RDA for adult men on the understanding that the mean pool size of vitamin C in healthy men is about 1500 mg which is maintained by the ingestion of 60–100 mg daily. No nutritional or health benefits have been shown to result from a body pool > 600 mg. Nevertheless, because of the relatively rapid turnover of vitamin C and the possible enhanced needs resulting from stress and physical exercise, the authors suggested that a mean body pool of 900 mg could be considered adequate to meet all nutritional requirements while providing a sufficient reserve (body pool < 300 mg threshold for scurvy). This means that the daily requirement for vitamin C in adult men would be 27 mg. A 40% safety margin would make it approximately 40 mg/day. Because of variations in body size, and therefore body pools of vitamin C, the RDA for adult women was set at 30 mg/day.

RDA for pregnant and lactating women

For pregnant women, daily 5 mg and 10 mg increments in the maternal RDA for vitamin C were recommended during the second and third trimesters of pregnancy to offset losses from the mother's body pool. For lactating women, a daily increment of 25 mg was recommended during the first 6 months postpartum.

RDA for infants and children

In the absence of specific information about the body pool and turnover rate for infants, an intake of 25 mg per day was recommended based on the vitamin C content of breast milk. The recommended intake for children was to be gradually increased to adult levels as a function of age.

RDA for the elderly

In the absence of a pathological condition that would influence vitamin C absorption or renal reabsorption, no increment was recommended in intake by the elderly.

Minimum or optimum requirements

It is clear that the vitamin C intake needed to prevent scurvy, 10 mg or even less, is very small. What is uncertain, however, is how much more than this is required to ensure good health. There is no clear link between the biochemical roles of vitamin C and scurvy. Thus, the amount of vitamin C necessary to prevent scurvy may not be equivalent to what is needed to satisfy the body's diverse enzymatic and non-enzymatic requirements.

Some investigators have reported that larger daily doses of vitamin C are beneficial in conditions apparently quite unrelated to scurvy (Irwin & Hutchins, 1976). For example, a study of vitamin C and physical working capacity showed that the subjects with the lowest serum vitamin C levels had the lowest aerobic capacity, and that an increase in serum vitamin C level was accompanied by a proportional increase in aerobic capacity, but only up to the vitamin C serum level of 0.8 mg/dl (Buzina & Suboticanec,1985). The serum vitamin C level 0.8 mg/dl corresponds to a daily dietary intake of about 80–100 mg, which is well above the FAO/WHO RDA. Where vitamin C and increased iron absorption are concerned, Hallberg et al. (1989) stated that the amount of vitamin C needed in the diet to achieve reasonable iron absorption is much higher than that required to prevent scurvy.

It has still not been established which biochemical function or functions best mirror the optimal dietary level of vitamin C. ***Where prevention of scurvy in emergencies is concerned, it can be agreed that food distributed to affected populations should cover the 30 mg FAO/WHO RDA.***

Factors affecting vitamin C reserves

Vitamin C reserves are affected by the following factors which influence vitamin C intake (Schorah et al., 1981):

- *Social class*
  There are social class differences in intakes of vitamin C that are probably associated with income.

- *Season*
  Where vitamin C intakes are lowest in spring, this is generally attributable to seasonal unavailability and high cost of fresh fruits and vegetables, and possibly to the consumption of stored vegetables with low levels of vitamin C.

- *Age*
  Decreased intakes by the elderly is the main factor influencing age-related changes in vitamin C reserves.

- *Institutionalization*
  There are increased losses of vitamin C during large-scale institutional food preparation (see chapter 'Stability in Foods').

Vitamin C reserves are also affected by the following factors that influence vitamin C metabolism (Schorah et al., 1981):

- *Sex*
  There is considerable evidence that mean plasma and leucocyte vitamin C concentrations are lower in males than in females and that this difference persists into old age. The reason for these sex differences is not known.

- *Smoking*
  There is general agreement that smoking lowers the level of vitamin C in both plasma and leucocytes even if the precise reason is not known. Some believe that it is due to smokers' reduced ability to absorb the vitamin.

- *Race/ethnicity*
  Large differences have been reported around the world for vitamin C reserves; some of the highest values are found in North America and some of the lowest in India, which may be predominantly diet-related. The nomadic tribes of the Sahel and the northern part of Nigeria and Ghana do not normally develop scurvy even on a diet almost devoid of fresh fruits and vegetables. However, Nicol (1958) and Watson (1976) noted the importance of sylvan produce from plant sources for covering vitamin C requirements. Schorah and others (1981) in turn suggested that it might be possible for some populations to synthesize vitamin C, for example in the case of malnourished Ghanaian children who apparently maintained surprisingly high plasma vitamin C concentrations. However, the possibility that this may occur should not influence the decision to intervene.

- *Acute disease*
  Early writers such as Lind noted that scurvy often followed infectious epidemics. In the 1930s, investigations into the effect of infection on vitamin C reserves showed that serum

levels in people with adequate vitamin C intake were markedly depressed by acute infection. The reason for such a change in metabolism during acute trauma and disease is unknown.

C *Chronic conditions*
Most sick people have low vitamin C reserves, for example in the case of gastrointestinal disease, liver disease, alcoholism, asthma and diabetes. A number of studies indicate that plasma vitamin C concentrations also decrease gradually throughout pregnancy. Lactation can lead to significant losses of maternal vitamin C—as much as 32 mg/day (Rajalakshmi et al., 1965; Salmenpera 1984).

Megadoses

It has been claimed that very large daily doses of vitamin C ($1 g per day) prevent, or are effective in treating common colds and other infections, psychiatric conditions, hyper-cholesterolaemia and atherosclerosis, cancer, and other diseases, while enhancing immunological responsiveness, wound healing, and physical performance (Irwin & Hutchins, 1976; Olson & Hodges, 1987). Large doses have also been said to lower blood cholesterol, facilitate iron absorption, and promote the mobilization and elimination of heavy metals such as lead, mercury, cadmium and copper. Linus Pauling recommended daily intakes of 2400 mg, which is equivalent to the amount rats produce calculated on the basis of body weight per day. However, such claims have not been supported by research. Although many controlled clinical studies have been conducted to test the protective effect against colds of gram-doses of vitamin C, most indicate only a small positive impact in terms of reducing the incidence, shortening the duration, and alleviating the symptoms of the common cold. It has been suggested that some of these benefits may be due to a placebo effect (Combs, 1992).

Hypervitaminosis/vitamin C toxicity

It is not known to what extent routine ingestion of very high doses of vitamin C seriously impairs health in a lasting way. Occasional large intakes of vitamin C may cause stomach cramps, nausea, and diarrhoea in some fasting subjects but have no long-term adverse effects. Several mechanisms prevent excessively high concentrations of ascorbic acid in blood plasma (Hodges, 1980). Only a certain amount of vitamin C can be absorbed, and if more is ingested it will be excreted in the faeces. The second line of defence is the kidneys, which excrete excess amounts. A third protective mechanism is that food generally contains small amounts of the vitamin. The frequency of reported toxic manifestations is very low relative to the number of persons routinely ingesting large doses (Olson & Hodges, 1987).

It has been specifically proposed that megadoses of vitamin C increase oxalate production (thereby increasing the formation of renal stones); competitively inhibit renal reabsorption of uric acid; enhance the destruction of vitamin B_{12} in the gut; intensify the enteric absorption of non-haem iron, thus leading to iron overload; result in mutagenic effects; and increase vitamin C catabolism that would persist after returning to lower intakes of the vitamin (Combs, 1992). These and other possible effects of high doses have been reviewed by Hornig and Moser (1981) and Rivers (1989), who conclude that ingestion of even massive amounts of vitamin C (up to 10 g/day) does not usually constitute a health risk for humans. Nevertheless, large doses are contraindicated in cases of renal insufficiency, chronic haemodialysis, unusual forms of iron overload, and in oxalate stone formers.

Supplementation frequency

RDAs are based on the assumption that people obtain the required nutrients daily. In reality, many people consume at least some nutrients only sporadically. Reliance on vitamin C supplements, e.g. tablets or highly fortified blended cereal-legume foods, may not be justified, especially if they are not consumed regularly. Data obtained from animal studies indicate that the frequency of nutrient supplementation is a factor that should be considered in establishing dietary recommendations (Snook et al., 1983). Human studies show that after single-dose administration, plasma levels return to their normal values in about 12 to 13 hours, no matter how much vitamin C has been consumed. This suggests that in order to maintain equilibrium in serum C levels, the vitamin should be ingested several times a day.

Snook et al. (1983) carried out a study to determine if subjects given a relatively large nutrient supplement (4 times the RDA) every 4 days maintained blood and urinary levels of the nutrient comparable to those of subjects given small doses (1/3 the RDA) with every meal. Results suggest that subjects adjust to receiving supplements of vitamin C on a periodic basis, which is contrary to the observation that serum levels maintain an equilibrium.

Sources of vitamin C

Availability in foods

Vitamin C, in the form of ascorbic acid and dehydroascorbic acid, is widely available in foods of both plant and animal origin. Fruits, vegetables and organ meats, e.g. liver and kidney, are generally the best sources. Plants synthesize ascorbic acid from carbohydrates. Most seeds do not contain ascorbic acid, but start to synthesize it upon sprouting, and it is probably present in high concentrations in rapidly growing stems, root tips, green leaves and pods. Although most animals can synthesize their own supply there is relatively little stored in their tissues and muscle meat is therefore a poor source of the vitamin. Fruits, especially citrus fruits, are a good daily source of vitamin C as they are generally eaten raw and are thus not subjected to cooking that can destroy the vitamin. Green vegetables are also a useful source, although they contain highly variable amounts, much of which can be lost in preparation and cooking. Tubers such as potatoes, are not a rich source, but since large quantities are often eaten, they can be a major contributor to meeting requirements. The vitamin C content of some vegetables, fruits and tubers is listed in Table 8 (Combs, 1992).

Among fruits, guavas, rose hips and various berries are rich sources (>300 mg/100 g) while most other fruits provide 10-90 mg/100 g. Starchy roots, tubers and starchy fruits contain appreciable quantities of vitamin C with cassava containing 40 mg/100 g. However, Watson (1976) reported that cassava flour and cassava meal processed from fresh cassava contained only 9.9 mg/100 g and 6.3 mg/100 g, respectively. Sweet potato contains, on average, 37 mg vitamin C per 100 g edible portion (West et al., 1988) and can be an important source of the vitamin since it can be fairly easily cultivated in cooler or hotter climates. Among vegetables, the leaves of amaranthus and sweet potato contain 100-150 mg vitamin C/100 g and other vegetables such as tomatoes, peas and beans 10-30 mg/100 g. The cassava leaf, although rarely eaten in many African countries, is very popular in parts of central and West Africa; it is a particularly rich source of vitamin C with an average of 740 mg/100 g. Peppers are also rich sources with about 740 mg/100 g, depending on the variety (Watson, 1976). Dried pepper powder contains considerable vitamin C and therefore can increase the vitamin C content of cooked food when used as a spice.

- dried peppers: unspecified 180 mg/100 g
- dried red peppers 12 mg/100 g

Breast milk is a good source of vitamin C that covers an infant's needs when full lactation is maintained. Infantile scurvy is seen only in artificially fed infants.

Varieties of plant produce are excellent sources of vitamin C and should not be overlooked. Even though they are not eaten in large amounts they are used regularly where available (Nicol, 1958). The following are some examples of sylvan produce found in northern Nigeria and northern Ghana (Nicol, 1958 and Watson, 1976):

- *Baobab fruit pulp* (373 mg/100 g) is made into an emulsion with water and used as an adulterant of milk or in sorghum and millet gruels.
- *Locust bean tree pulp* (190 mg/100 g) is stirred into gruels and is made into a sweet syrup or eaten as it comes from the pad.
- *Desert date pulp* (140 mg/100 g) is eaten uncooked when the fruit is ripe.

Brand et al. (1982) found that a wild fruit (*Terminalia ferdinandiana*) used by Australian aboriginals, and eaten especially by children, may well be the richest natural source of vitamin C in the world with between 2300 mg and 3150 mg per 100 g edible fruit. Other rich sources are the amla fruit in India (600 mg/100 g) and the Barbados cherry (1000-2330 mg/100 g). Nicol (1958) reported the great importance of sylvan produce in the arid parts of Nigeria where sorghum and millet, which contain no vitamin C, are the staple foods. However, habitual yam-eaters, who may eat more than 1 kg of yam per day, can derive all their vitamin C requirements and more from this food alone. Watson (1976) also reported that in Ghana many of the starchy roots, tubers and starchy fruits are eaten in appreciable quantities in the coastal and forest zones and would probably contribute adequate amounts of vitamin C to the diet. However, in the northern regions, cereals form the bulk of the diet and sylvan produce may play an important role in covering the population's vitamin C requirements.

The report by a joint FAO/WHO expert group (1970) stated that people consume 100-350 mg per day of vitamin C where starchy roots and tubers are the staple foods and 10-70 mg per day where cereals are the staples. Besides the kind of staple food consumed, the season of the year is an important factor influencing vitamin C availability and intake. Clearly there are seasonal variations in the supply of fruits and vegetables but also variations in the amount of vitamin C contained especially in vegetables. Vitamin C in green vegetables is highest when the plants are growing rapidly (FAO/WHO, 1970).

Vitamin C intake levels in various parts of the world are found in annex. Vegetables contribute some 60-85% of the total intake in developing countries, but only 20-50% in Europe and the USA. Fruits contribute 1–20% of intakes in developing areas and 15–45% in the West (FAO/WHO, 1970).

Camel's milk, which is an important source of vitamin C for nomads in Somalia, contains approximately 6 mg/100 g, or about three times the amount in cow's milk. If not consumed fresh, the milk is traditionally soured and stored in opaque containers, which preserves the vitamin. The nomads traditionally consume up to 4 litres of camel's milk per day, thereby providing more than adequate quantities of the vitamin (Magan et al., 1983).

Germination

All mature, dry seeds are nearly or entirely devoid of vitamin C. This is also the case for many types of grain (wheat, rice, maize, etc) and legumes (peas and beans), as well as for flours made from them. With germination, however, vitamin C synthesis begins almost immediately. During World War I, in the absence of fresh fruits and vegetables, germinated pulses were recommended in Dutch army rations as a source of vitamin C (Carpenter, 1986). Germinated pulses are common in the diets of people in certain parts of India and have also been used in child welfare centres as an inexpensive source of vitamin C (Bhagvat & Rao 1942). Sprouted pulses were also used in India and by the Russians during World War II.

Bhagvat & Rao (1942) carried out a study to see what effect germination, and cooking and drying, have on the vitamin C content of certain pulses and cereals. The seeds were soaked for 12 hours in tap-water, spread out between 2 layers of cloth, kept moist by sprinkling a bit of water, and kept at room temperature (21°–25°C) in diffused daylight. Very little vitamin C was found after merely soaking the seeds in water from 4 to 12 hours. However, pulses and cereals rapidly synthesized vitamin C immediately after the initiation of germination. The maximum amount of vitamin C was synthesized within 48 hours, after which it remained constant for 4 days. Germinated pulses were a better source of the vitamin than germinated cereals e.g. germinated soya beans contained 10.8 mg/100 g dried material, germinated pulses contained between 30–50 mg/100 g dried material, and germinated wheat 8.8 mg/100 g dried material. At higher temperatures germination took place more rapidly than at lower temperatures, but the amount of synthesized vitamin C was less.

In the Ajmer famine of 1940, in which germinated Bengal gram had been distributed on a wide scale, it was observed that the people often threw away the shoot before eating the pulse. A considerable amount of vitamin C is lost if the sprouts are thrown away since the vitamin is apparently formed in the cotyledon and then transformed to the rapidly growing sprout. In India germinated pulses are sometimes consumed raw, but they are also commonly cooked. In order to minimize vitamin C loss, Bhagvat & Ras (1942) state that it was advisable not to prolong cooking beyond half an hour and to cook the germinated pulses in a slightly acid medium. The study also looked into the losses in respect of drying germinated pulses, which was between 11 to 26% of the vitamin content. Furthermore, it showed a progressive loss of the vitamin up to 80% when dried samples were kept at 37°C for approximately 50 days. These investigations have shown that the use of dried germinated pulses as an anti-scorbutic cannot be recommended because the loss of vitamin C during storage is too rapid. However, the authors state that the ease with which ordinary dry pulses can be germinated regularly renders unnecessary their previous germination and drying for storage. Germinating pulses and beans are potential sources of vitamin C in rations for refugee communities with poor vitamin C status. Many species of pulses produce significant quantities of vitamin C up to 5 days following germination although subsequent cooking caused marked loss of ascorbate (Riddoch et al., 1998).

It is important to note that dietary vitamin C in natural products has a distinct advantage over synthetic vitamin C, e.g. in tablet form, since food sources also provide a number of other important micronutrients, bioflavonoids, carotenoids, and pectin.

Stability in foods

Vitamin C in food is unstable in neutral and alkaline environments and when exposed to oxygen/air, heavy metals (iron, copper), and light and heat (which accelerate the course of the oxidation and extraction processes). The longer the exposure the greater the loss. Vitamin C stability is favoured by an acid environment and in the presence of other antioxidants, e.g. vitamin C in fresh fruits and vegetables, and in fermented products.

Losses

Vitamin C is quite unstable in foods, especially under adverse conditions of storage and preparation. The vitamin generally occurs in foods that are quite acidic or in foods containing antioxidants that help to protect or preserve vitamin C content. Vitamin C in fresh whole fruits and vegetables is quite well preserved for days or weeks at a time. When foods are processed the vitamin may be exposed to oxygen, metallic surfaces, or high temperatures, all of which hasten oxidation. Cooking water is usually discarded and vitamin C, which is water soluble, is also lost in this way. Food Composition Tables list vitamin C values for raw foods minus 10–25% for expected losses. However, such calculations usually overstate the true intakes of the vitamin.

Natural raw food

Wide variations occur in the vitamin C content of raw foods depending on the conditions of feeding, growth, etc. For example, the vitamin C content of tomatoes is lower when the yield is increased with high levels of artificial fertilizers (Carpenter, 1986).

Vitamin availability

Vitamin C can be present in a form in which it is not readily available, e.g. vitamin C in cabbage is present in the bound form, ascorbinogen, which is poorly absorbed by humans. Food Composition Tables express the total content based on chemical analyses which does not take into account the vitamin's true bioavailability (Marks, 1975).

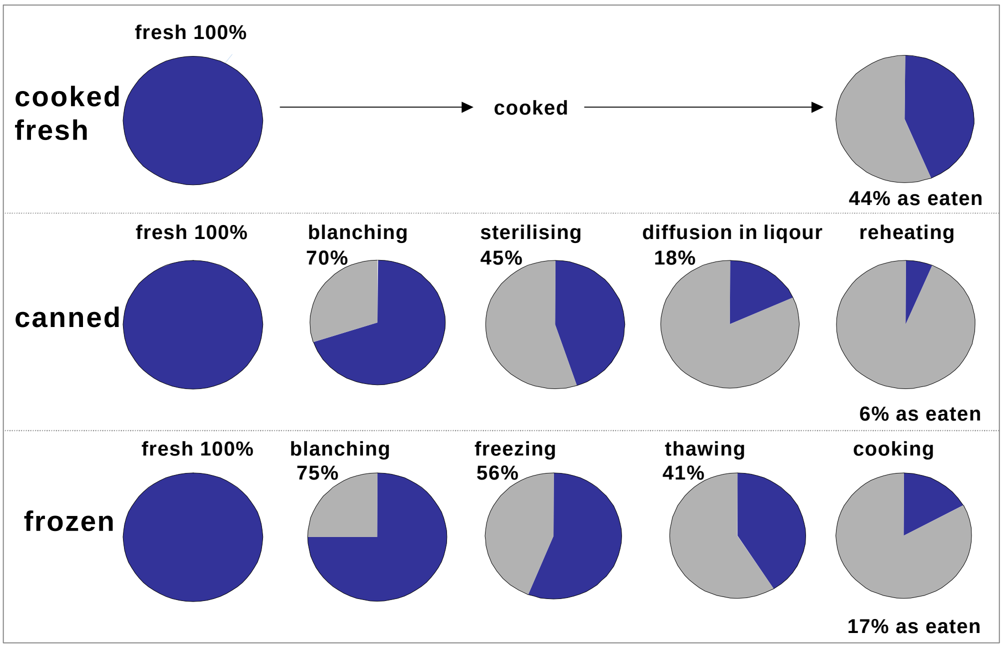
Losses before, during and after processing

Fruits and vegetables that are harvested a long time before they are consumed undergo heavy losses of vitamin C through enzymatic decomposition. For example, the vitamin C content of apples stored under domestic conditions falls to about 1/3 of the original value after only 2–3 months. Green vegetables stored at room temperature lose practically all their vitamin C after only a few days, though losses are lower when stored at 0ºC. Newly harvested potatoes have a vitamin C content of about 30 mg/100 g; this figure falls rapidly to about 8 mg/100 g after 8–9 months storage and to virtually nil after another 2 months (Marks, 1975).

Foods are processed in various ways to lengthen the time they can be stored, e.g. by canning, freezing, drying, sterilization and irradiation, and vitamin C losses vary depending on the method used. Before canning or freezing, vegetables are "blanched", i.e. exposed briefly to boiling water or steam to inactivate enzymes which have a detrimental effect during storage. Loss of vitamin C due to blanching is between 13–60%. Short exposure to high temperatures is less harmful than longer heating at lower temperatures. The vitamin C losses during blanching are caused either by oxidation or by leaching; and small pieces of vegetable lose more vitamin C than do large pieces. Losses can be reduced if vegetables are cooked rapidly after blanching. See Figure 2 for the percent of vitamin C retention during the processing and cooking of peas treated in different ways.

Figure 2: Percentage of vitamin C retention during processing and cooking of peas treated in different ways

Vitamin C loss also occurs during heat sterilization even though oxygen is excluded during this



Source: Marks 1975

process. Foods stored in cans are relatively stable and losses after storage for 2 years at 10ºC amounted to only about 15% of the initial value. Variations are found, however, depending on the degree of enzymatic destruction that has occurred during the blanching and sterilization phase (Marks, 1976).

Freezing can be an effective method of food preservation since vitamin losses due to chemical decomposition are minimal. However, rapid decomposition may occur during thawing, especially in vegetables. Grant and Alburn (1965) have shown that vitamin C oxidation is faster in ice than in water. For example, frozen orange juice concentrates lost about 10% of their vitamin C content during 12 months storage at -23ºC. The figures in the literature for vitamin C losses during deep freezing vary considerably, the average being 25% of the initial value.

Freeze drying is probably one of the best preservation methods as far as vitamin retention is concerned, although it is not widely practised. Hot air drying of vegetables results in a 10–15% loss of vitamin C under the most favourable conditions. The commercial dehydration of potatoes can cause losses of 35-45% (Berry Ottaway, 1993).

The stability of vitamin C in soft drinks and fruit juices varies widely according to the composition and oxygen content of the solution. It is very unstable in apple juice but quite stable in blackcurrant juice, possibly as a result of the protective effects of phenolic substances with antioxidant properties. Light can have an impact on the stability of vitamin C in milk with the extent of losses being dependent on the type of container in which the milk is stored and the length and conditions of exposure. Bottled orange drinks exposed to light have been found to lose up to 35% of their vitamin C within 3 months.Vitamin C losses in milk are around 25% during pasteurisation and about 60% during sterilization. Up to 100% of vitamin C content is lost in UHT (ultra-high temperature, short time treated) milk stored for 3 months (Berry Ottaway, 1993).

Grain milling to produce white flour minimizes the content of bran and germ and consequently vitamin C. White flour retains half the amount of vitamin C found in whole wheat flour.

Losses during food preparation before cooking

Major losses of vitamin C occur before cooking occur when vegetables are washed in large amounts of water and left to stand in water. Potatoes that are skinned prior to cooking lose more vitamin C while cooking (see Table 10). The slicing and dicing of vegetables will increase the rate of loss before and during cooking.

Ions of copper and iron play a significant role in vitamin C oxidation and thus the selection of process/preparation equipment can have a marked effect on the stability of the vitamin in food and drink products. Contact with copper, bronze, brass, steel or black iron surfaces should be avoided and only stainless steel, aluminum or plastic should be used. (Berry Ottaway, 1993). A steel knife quickly becomes dull if used for slicing lemons. The iron ends up in the lemon juice and vitamin C activity is reduced.

Losses during cooking

Long, slow cooking and slow cooling, especially with exposure to oxygen, causes greater vitamin C losses than does rapid heating and cooling, for example in a pressure cooker (Marks, 1975). However, whatever the method, minimum losses of about 50% can be expected.

Studies investigating the effect of cooking method and storage on the vitamin C content of Malaysian leaf vegetables, showed that holding leaves for 24 hours after harvest in the normal high temperature/high humidity environment resulted in losses of up to 85% of the vitamin C present in fresh produce. When leaves were boiled in water, cooked in coconut milk, or fried, their average vitamin retention was 45%, 56% and 66%, respectively. Vitamin retention in leaves was reduced due to the leaching of the vitamin into water over time when cooked vegetables were allowed to stand. However, even in the drained and fried leaves, only 30% of the initial vitamin C was retained after 4 hours. In the same study cassava leaves were first boiled to remove hydrocyanic acid and then cooked in coconut milk. The result was an average of 30 mg vitamin C per 100 g of cooked weight compared to 358 mg per 100 g of fresh leaves. Although the cooked vegetable contained less than 10% of the vitamin C of fresh leaves, this still represents a significant amount. Thus, in a Malaysian setting, vitamin C losses during cooking can be reduced by frying vegetables, cooking them in coconut milk (total retention in leaves + liquid was 70%) and consuming the coconut milk with the vegetables, and reducing as much as possible the time between cooking and eating.

Nicol (1958) looked at vitamin C in the diets of rural populations in Nigeria and concluded that the commonly used methods of cooking starchy roots did not destroy all the vitamin C present at the time of purchase. Yam and cassava tubers lost, on average, 50% of their vitamin C content during cooking. In the case of sweet potatoes a loss of 75% occurred if they were boiled after peeling, but only 56% if they were cooked without being peeled. Yam and cassava flour, both prepared by first soaking the uncooked tubers in water, and then pounding, sun-drying and grinding them, contained little vitamin C and the cooked food made from the flour contained only traces of the vitamin.

Watson (1976) studied the effects of cooking on the vitamin C content of plant foods in Ghana. Starchy roots and tubers and starchy fruits were found to retain some vitamin C after cooking, while the greatest loss occurred in leafy vegetables when boiled. There was only a 20% loss of vitamin C in yams after cooking compared to findings by Nicol (1958) who reported a 50% loss. Many of the leafy and other vegetables are incorporated into soups, stews and sauces which, because they are often prepared in large quantities for use over time, are subject to reheating before being consumed. Although this may lead to additional losses of the vitamin, heating food thoroughly is of course a vital food safety measure.

Hallberg et al. (1982) demonstrated the negative impact on vitamin C content of prolonged warming of food. The vitamin C content of food kept at 75ºC for 4 hours was markedly lowered, with the greatest reduction occurring during the first hour. The study showed the importance of either preserving or restoring the vitamin C content of meals prepared on large a scale, e.g. in schools and other institutions. In the study vitamin C was restored by sprinkling vitamin C powder onto the cooked food.

Retaining maximum levels of vitamin C during meal preparation

The best food preparation and cooking methods for preserving vitamin C include:

- Using fresh foods.
- Using a small amount of water to prepare foods.
- Not cutting vegetables into small pieces before cooking.
- Covering cooking pot to reduce time, or using a pressure cooker where available.
- Cooking at high temperature for a short period.
- Not storing cooked foods prior to eating them.

Adding vitamin C to foods

The loss of vitamin C during food processing is such that some people are in danger of consuming inadequate amounts of this vitamin to maintain normal health. Vitamin C can be added in various ways (Marks, 1975):

- **Re-vitaminization.** Restoring the vitamin content to what it was prior to processing, e.g. the production of dehydrated potatoes for “instant mash”, which can result in a total depletion of vitamin C, calls for adding vitamin C to the product.

- **Standardization.** Compensating for natural variations in vitamin content, e.g. vitamin C added to fruit juices.

- **Enrichment.** Adding more than the amount of the vitamin already present, e.g. vitamin C in certain soft drinks and fruit juices.

- **Vitaminization.** Using certain foods as vitamin C carriers, e.g. blended cereal/legume flours that are primarily intended for use in areas where malnutrition is a problem and where extensive vitamin enrichment of products is thus desirable.

Strategies to prevent scurvy in large refugee populations

Background

The most effective way to prevent micronutrient deficiencies in general and scurvy in particular is to consume a diet containing a variety of foods, including fresh foods. Emergency food supplies, however, usually consist of a staple (cereals), an energy source (oil), and a protein source (pulses), all of which contain virtually no vitamin C. Populations depending entirely on such a limited range of foods for more than two months run the risk of developing scurvy. According to WFP (1991), "where people are more or less totally dependent on food aid rations for long periods, without opportunities to produce or obtain other foods by trading or other means ... a range of foods should be assured, including some fresh foods wherever possible (even if only on an occasional or irregular basis) in order to supply a diet which meets all essential nutrient requirements".

It is generally agreed that there are problems associated with meeting these principles in practice and that no single strategy that will ensure that adequate quantities of all essential micronutrients are provided to all demographic groups of refugees in every camp. Toole (1992) stresses that at every stage of an emergency programme, refugees should be provided with opportunities to diversify their dietary intake through free exchange of rations in local markets, cultivation of vegetables in camp gardens, and employment programmes.

Main approaches

The main approaches to preventing the onset of scurvy in emergency situations affecting large populations are as follows:

- Providing food rations containing adequate amounts of vitamin C by increasing the variety of the food basket and regularly including fresh fruit and vegetables.
- Providing sufficient food in the ration to allow refugees to sell the surplus for other purposes. It has been found that refugees with the highest value of rations received did, in fact, consume the greatest amounts of fruit and vegetables (Hansch, 1992).
- Fortifying current relief commodities with vitamin C, e.g. providing fortified blended cereal-legume food in the general ration in sufficient amounts to cover vitamin C requirements.
- Providing vitamin C supplements in the form of tablets at least weekly.
- Encouraging and facilitating, where feasible, cultivation by refugees of fruits and vegetables in home gardens.

Several of these options have been tried in various refugee settings with varying degrees of success (Berry-Koch et al., 1990). The advantages, disadvantages and feasibility of each approach are discussed below.

Distribution of fresh foods

Advantages

- Local fresh foods allow refugees to maintain a normal well-balanced diet.
- Natural sources of vitamin C provide other nutrients beneficial for health.
- Local procurement of fresh fruit and vegetables may enhance production by indigenous populations while providing economic support.

Disadvantages

- Fruits and vegetables are perishable and subject to spoilage, especially during transport, and cannot be stored for long without drastic reductions in vitamin C content. Regular supplies are thus necessary.
- It is difficult to purchase sufficient quantities on the local market for large refugee populations.
- The cost of procuring and transporting fruits and vegetables is usually quite high.
- Large quantities of fruits and vegetables purchased locally can create shortages and increase prices on the local market to the disadvantage of local consumers.

Feasibility

The limited amounts of citrus fruit, guavas and camel's milk distributed to refugees in Somalia proved to be very difficult logistically and expensive, and this intervention was discontinued (M. Dualeh, UNHCR, personal communication; Desenclos, 1989; WHO, 1989). The feasibility of providing foods such as onions and potatoes has not been sufficiently tested in these settings.

Vegetables are being distributed, e.g. to refugees in Nepal. Procurement of sufficient quantities and related logistics seem to be under control. However, Nepal's refugee population of 85 000 is small compared to the millions in Africa and fresh vegetables are much more readily available in Nepal than in the arid areas of the Horn of Africa.

Exchange of rations/extra rations

Advantages

- The most convenient option for donors would be to offer surplus foods. This would mean no changes in bureaucratic procedures.
- Extra food in the ration would allow refugees to trade for a more varied and balanced diet.

Disadvantages

- There is likely to be no time or immediate food surplus for distribution in the case of a large and rapid influx of refugees. Frequently, the food distributed is even less than the normal general ration agreed by the agencies.
- Markets would have to be accessible to refugee populations, which is often not the case in remote areas or during the early stages of an emergency. Local supplies of relevant foods would have to suffice.
- Increased local trading may disrupt food prices to the detriment of local producers.
- Nutrition education would be necessary to encourage refugees to trade for vitamin C rich foods.

Feasibility

Since food aid, which provides very little vitamin C, has not been helpful in preventing or controlling scurvy, especially in Africa, the main source of this vitamin has been local markets. Experience from around the world repeatedly confirms that refugees trade donated foods in a way that significantly improves their overall diet. Large amounts of some foods are sold, whether inside or outside refugee camps. Some sales are made by individuals while others are made by households or even by camp-wide committees. For example, Hansch (1992) reported that 10% of soy-blended flours were sold to outsiders and 60% swapped within camps. The flour was also fed to swine and poultry.

Donors often feel that people who sell relief foods do not need them. In fact, it is the poorest, most desperate refugees who have to sell some part of their rations. In contrast, relatively well-off refugees have other sources of income and are thus afforded the luxury of being able to consume their food rations (Mason et al., 1992).

As the 1988 conference, Nutrition in Times of Disaster, concluded:

> *Attempts to manage the problem [of micronutrients] have not been successful. The obvious solution is either to provide a nutritionally full and adequate ration or to permit trade that will aid recipients to obtain other foods to make up an adequate ration. Trading for spices and condiments should be permitted to break the monotony of the diet and to improve the palatability of donated foods.*

Referring to Mozambique, Wilson (1989) reported that:

> *Refugees exchange food rations as part of their quest to improve the quality of their ration: to turn several dried commodities into a diet that is physiologically and culturally acceptable, and biochemically balanced. Generally, this need undermines the calorific, and sometimes even the protein and fat content of the diet, due to poor exchange rates. However, it remains essential to understand refugee exchanges in the light of an absolute requirement to make up for items missing in the diet, such as fresh vegetables. In all camps and in the self-settled areas one of the main means by which refugees obtain green vegetables is through exchange of food aid, generally flour ...*

Christensen (1982; 1984) noted that refugees in Pakistan, Mexico and Somalia obtained access, by trading, for other types of food such as fresh fruits and vegetables.

In conclusion, refugees themselves often solve their micronutrient problems by selling food to enhance dietary variety. Problems have arisen where refugees do not have access to markets and are entirely dependent on food aid, particularly when the general ration is substantially short of requirements.

Fortification of relief food

Fortification is a convenient way of preventing deficiency diseases by providing food with added micronutrients.

The food item to be fortified:

- should be widely consumed by the refugee population;

C should be consumed with little variation from person to person and from day to day;
C should be of a cost and nature to make the fortification process economically feasible on an industrial scale;
C should result in no change in organoleptic characteristics.

Advantages

C Providing certain nutrients simultaneously in the same food improves the utilization of certain vitamins and minerals, e.g. vitamin C enhances the absorption of iron;
C Providing nutrients through the regular food supply and distribution system reduces costs.

Disadvantages

C The shelf life of fortified milled cereals is reduced compared to unfortified unmilled cereals.
C Regular quality control is essential.
C When fortified food is cooked too long, vitamin C loss can be as much as 90% (study undertaken by the Refugee Health Unit on CSB, Somalia, 1989).
C A fortified commodity is more expensive than an unfortified one.

Feasibility

Consistent with the above definition of an ideal food vehicle for fortification, it is clear that staple foods should be given priority. Refugee rations usually include cereals, oil, pulses, salt, sugar, and cereal-legume blends. Beaton (1995) recommended a cereal fortification premix for use with milled maize, and wheat- and sorghum-based rations. The recommended vitamin C content was 110 mg per 1900 kcal of the ration, which takes into account a 25% loss during storage. He suggested that the premix could be added during:

- Centralized fortification of staple cereals.
- Community-level fortification (camp-level) of all cereal before distribution to refugees;
- Household-level fortification of cereal, after distribution, when “households” grind the cereal or otherwise prepare it for consumption.

However, some experienced field workers have expressed doubts about the willingness of those responsible for household cooking to use such a premix, and to use it in the correct proportion.

The following observations can be made regarding vitamin C fortification of commodities in the general ration.

Fortification of cereals

Flour. Technology exists for fortifying cereal flour with vitamin C, but losses during storage, transport and preparation have to be carefully assessed.

Whole grains. Several studies on the fortification of whole grains with vitamin C have been undertaken, e.g. by USAID. The main constraint with this technology—sucrose syrup solutions are sprayed on the surface of the grains—is the product's limited shelf life and the stability of the vitamin after exposure to heat during shipment (heat exposure can be as high as 40–50°C) and during milling and pounding (mechanical heat). Vitamin C losses during exposure to humidity and oxygen, in addition to losses during cooking, could be quite high. An advantage of un-milled cereals is that whole grain can be more easily salvaged when bags break during transportation.

Simulated rice kernels have been developed for rice fortification. Vitamin A and other vitamins can be incorporated into the simulated kernel mix which is added to normal white rice at an appropriate proportion (e.g. 1:200) to provide the proper nutrient level in the fortified rice. During cooking the nutrients are released from the premix kernels and evenly distributed throughout the product. The simulated rice kernels have the same shape and colour as the regular rice and therefore cannot be picked out and discarded as foreign particles before cooking. However, the fortification of rice with vitamin C could be a problem because of the high vitamin losses if the cooking water is discarded.

Fortification of sugar

Sugar could be a staple vehicle for vitamin C fortification and it is likely to be cooked for a shorter period than cereals. Peter Ryffel (Roche, personal communication) stated that from a technological viewpoint, sugar is an ideal vehicle for the vitamin, however the stability of vitamin C would have to be assessed. Because of high humidity in many countries the problem of 'caking' of the sugar and its effect on the vitamin C content would also have to be looked into. There seems to be no practical experience in vitamin C fortification of sugar.

Sugar in beverages fortified with vitamin C helps to protect the vitamin. One of the best vehicles for the fortification of vitamin C are sweets (personal communication, Roche). The hydroxyl groups in the sugar tend to seal the vitamin off from the effects of oxygen. From a technological point of view sugar seems to be an ideal vehicle for fortification with vitamin C. No alterations of colour, taste and texture of the sugar is expected when fortified with vitamin C powder.

In South Africa there are two well equipped sugar mills ('Tongaat' and 'Ilivo') that are working on the fortification of sugar with vitamin A. The people are strongly motivated and would most probably willingly agree to carry out a pilot study using vitamin C. However one would have to consider the higher costs of sugar purchased there. Also in Kenya the 'House of Manji' produces blended cereal-legume foods and would have the equipment to blend sugar and vitamin C powder. Expertise would be available there to follow up on the study and to monitor the process.

Oil and ***water*** are other potential vehicles for vitamin C fortification and will be discussed in more detail in the next section.

Fortification of blended cereal-legume foods (blended foods)

Fortified, pre-cooked cereal-legume blends have recently been added by WFP/UNHCR to the general ration mainly as a vehicle for micronutrients. Originally they were designed for the targeted feeding of malnourished children.

Advantages

- Blended foods are usually precooked, which means less time and fuel is needed for final cooking. The loss of vitamin C during cooking is therefore less than with non-precooked fortified cereal flour.
- The fortified commodity could be kept as a contingency stock for immediate mobilization when required. However, vitamin C loss during storage needs to be taken into consideration.

Disadvantages

- Vitamin C levels in the size of ration (30 g) currently distributed are too low.
- It is questionable whether the general population requires blended foods with their high protein content.

Feasibility

The fortification levels of currently available blended foods would need to be adapted if they were to be used as a vehicle for micronutrients, including vitamin C, for the general refugee population. The current ration of 30 g, at a fortification level of 30–60 mg of vitamin C per 100 g, does not cover daily requirements for vitamin C. Either the ration or the fortification level has to be increased. The following points would also have to be considered when choosing blended foods as the vehicle for vitamin C:

- How is the food prepared and how much vitamin C is lost in the process?
- Do all family members consume the food regularly (scurvy in refugees has been seen mainly in adults)?
- Is the food traded, swapped, fed to animals, etc.?

Blended food is used for rehabilitating young moderately malnourished children; it may account for 50% or more of their energy intake. Concern has been expressed (ACC/SCN, 1995) that an adapted blend used in the general ration may provide too high levels of some micronutrients—though not vitamin C—for young children. It was therefore suggested that the use of two blends should be investigated, the nutrient content of each being tailored for a specific purpose. The question arises here whether it would not be more convenient to fortify the staple cereals provided in the general ration instead of developing 2 cereal-legume blends.

Research carried out by OXFAM/UNHCR looked at the usage of blended foods in an emergency at the household level. In addition it investigated refugee preferences for a range of ration and non-ration foods, and 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 was shown to involve major issues of technical and operational feasibility in two Africa sites which would need to be dealt with for successful implementation of the use of fortified cereals in an emergency (Mears & Young, 1998). A study conducted by the Committee on International Nutrition (1997) suggested that much higher levels of fortification would be required depending on the ration size and that increasing Vitamin C fortification of all blended foods was not cost-effective.

Supplementation

Advantages

- Supplementation with vitamin C tablets is very specific for treatment and prevention.
- It is a politically visible form of assistance.
- The actual cost of vitamin C tablets is relatively low compared to other relief items.

Disadvantages

- Vitamin C tablets have to be distributed at least every 7–10 days.
- Procurement, transport and storage of large amounts of vitamin C for mass distribution is logistically difficult. Urgent air-shipped consignments are expensive.
- Non-compliance is a major problem.

Feasibility

Attempted direct supplementation of an entire population to control scurvy has not been effective in refugee camp trials. Problems include distributing tablets at least once a week to large refugee populations in unorganized camps. Compliance has also been low, and in some instances tablets were accumulated and sold in the market. A strong education component is needed to convince users of the importance of vitamin C as well as a well-established network for its distribution. However, the controlled supplementation of pregnant and lactating women at mother-baby clinics in many camps and is one way of targeting a group at risk.

Promotion of kitchen gardens

Advantages

- Vegetables that are culturally acceptable can be grown by refugees themselves, e.g. peppers, onions, sweet potatoes and tomatoes, which have adequate amounts of vitamin C and are easily grown.
- Because vegetables are locally available there would be no loss of vitamin C due to transport and storage.
- Once established, kitchen gardens would be more easily sustained compared to other options to prevent scurvy.

Disadvantages

- The promotion and establishment of kitchen gardens takes time and is usually not feasible during the emergency phase, the first few months after a refugee influx. It is precisely during this phase that the provision of vitamin C is so important.
- Seeds, water, land and technical expertise are required.
- Seasonality of certain vegetables could be a problem in certain areas.
- Education would be important to promote production of vitamin C-rich produce.

Feasibility

Kitchen gardens were common among refugees from Chad in the Darfur province of Sudan during the drought of 1985–86. Community vegetable gardens in the Salvadoran camps in Honduras provided fresh vegetables to the entire camp population in the late 1980s. In Mesa Grande, 11 000 refugees grew their own fresh vegetables through large, in-camp communal gardens. Many Bhutanese refugees in Nepal grow their own vegetables. However, in large refugee populations in Africa this strategy has not been sufficiently promoted. All too often the norm is that refugees do not/are not able to cultivate to diversify their diets. Availability or provision of enough water for small-scale horticulture as well as for personal use is an important facilitating factor. In particular, growing potatoes, sweet potatoes or other tubers is relatively easy and the product provides energy as well as minerals/vitamins, thus permitting exchange of dry rations (cereals) for other needed commodities.

Other options

Fortification of oil

It can be assumed that oil in the general ration is consumed by all family members. Vitamin C (ascorbic acid) is not soluble in oil. However, there are various oil-soluble derivatives of the vitamin, the most common being ascorbyl palmitate. Chemically it is an ester of ascorbic acid with the fatty acid being palmitic acid. It is very soluble in alcohol (10 g/100 ml) but has a low solubility and poor rate of dissolution in oil (30 mg/100 ml at room temperature). Forty-one percent of ascorbyl palmitate is ascorbic acid and thus oil that is fully saturated with ascorbyl palmitate would provide only 12 mg vitamin C per 100 ml of oil. A daily ration of 20 ml of oil would contribute 2.5 mg vitamin C, which does not include losses occurring during storage and preparation. This extremely low amount of vitamin C would not cover minimal requirements to prevent the onset of scurvy.

As Rivers (communication to UNHCR, 1988), has observed, with regard to fortification of oil with vitamin C:

- Ascorbyl palmitate supplementation would not prevent scurvy but would delay the onset of the disease, which would provide more time for other interventions to be put in place.
- 80 ml of fortified oil per day could prevent scurvy.

Harrell-Bond et al. (1989) suggested that ascorbyl palmitate would be a suitable derivative of vitamin C for the fortification of oil and skimmed milk powder, and that these fortification possibilities should be seriously considered by international agencies responsible for feeding refugees.

Ascorbyl palmitate is used as an antioxidant by the food industry. Also, tocopherol (vitamin E) is usually added, thereby increasing the anti-oxidative effect of the components and allowing the amount oxidised to be reduced. The result is that the antiscorbutic properties of ascorbyl palmitate are protected to a large degree. Many foods, especially those of vegetable origin, contain tocopherols and ascorbic acid as natural antioxidants.

The low solubility and poor rate of dissolution of ascorbyl palmitate have led to the development of special commercial products. Roche has developed a form in which ascorbyl palmitate has been pre-dissolved in lecithin. In this “solubilized” state, ascorbyl palmitate is significantly easier to dissolve in oil, e.g. 300 mg ascorbyl palmitate takes 90 seconds to dissolve in 1 litre of oil at 110°C, whereas the same amount of ascorbyl palmitate in the form of the antioxidant mixture takes 90 seconds to dissolve at a much lower temperature (45EC).

Ascorbyl palmitate is stable as a solid, in crystalline form, as well as in the concentrated solubilized form of the antioxidant mixture. During storage of highly diluted oil there is a continuous decrease of ascorbyl palmitate content and the oil should not be heated to temperatures above 105EC under atmospheric conditions and in the presence of oxygen. However, the antioxidant mixture seems not to be the appropriate method for vitamin fortification since 75% of the product is lecithin and only 40% of the ascorbyl palmitate, which makes up 25% of the mixture, is vitamin C. The advantage of the 200–300 ppm of vitamin C present is therefore minimal. It is also very expensive (±US$ 54/kg) compared to vitamin C powder (±US$ 13.50/kg). In addition, when 500 mg per litre is dissolved in oil a slight metallic taste develops (Roche, personal communication).

Rivers (communication to UNHCR, 1988) suggested a second approach to fortifying oil with vitamin C: disperse vitamin C, or a derivative, in the oil thereby creating a suspension rather than a solution. He tried making suspensions of both finely powdered ascorbic acid, which is commercially available, and ascorbyl palmitate and found that stirring finely powdered vitamin C into oil gave a suspension which took more than 24 hours to clear. His observation was that 20 ml of oil contained at least 30 mg of vitamin C for 24 hours. The exact concentration thus depends on when the vitamin C is added to the oil, when the oil is distributed, and when it is consumed. However, it can be concluded that the amount of vitamin C consumed by using oil as a vehicle would not cover the requirements necessary to prevent scurvy. Ryffel (Roche, personal communication) states that oil is not an ideal vehicle for vitamin C because of problems of low solubility.

It has been suggested that “micro-encapsulation” of vitamin C in vegetable oil should be a subject for operational research with oil possibly serving as the vehicle for larger amounts of vitamin C. However, discussions with Roche showed that the technology of micro-encapsulation to stabilise vitamin C in oil is not cost-effective. The fat-coated forms of vitamin C are 2–3 times the price of regular vitamin C and a special coating can cost even 3–6 times as much. Coated forms protect the vitamin and therefore increase its stability, though not its solubility, in oil. In addition, too much coating could decrease the vitamin’s bioavailability.

Fortification of water

The addition of vitamin C to refugees’ water supply has often been suggested as a possible immediate intervention in times of emergency. Water is trucked in and stored in containers, usually rubber-lined tanks, while metal containers are also used at the household level. Iodine and chlorine are usually added to the water before distribution. Harrell-Bond and others (1989) have stressed the instability of the vitamin, especially when in contact with iron and when stored at the ambient temperature encountered in semi-arid regions.

Vitamin C in an aqueous solution tends to undergo rapid oxidation due to atmospheric oxygen (air) and when it comes in contact with metals, e.g. iron and copper. If the water has a high iron content the stability of the vitamin is low. The pH of the water is also important, the vitamin being most stable when the pH is 3–5.5. Vitamin C reduces many organic reducible substances such as iodine. The interaction of vitamin C with chlorine and iodine depends on the concentration of these two elements in the water. Stability trials have shown that 50–200 ppm vitamin C added to chlorinated drinking water (0.3 mg/l) is rapidly degraded within a few hours (Roche, personal communication).

Hornig and Moser (1981) reported that vitamin C in tap water kept at room temperature becomes more stable with increasing concentrations of vitamin C and that it is rapidly oxidized below a concentration of 100 mg/l water. After one day (24 hours) at room temperature a solution with 10 mg vitamin C per litre water had zero vitamin C left, a solution with 100 mg vitamin C per litre water had 2%–3% of the vitamin left, whereas a solution with 500 mg per litre still had 50% of the initial vitamin C content. Adding sugar to water (about 6%–12%) increases the stability of vitamin C in water.

Vitamin C powder has been added to jugs of water in schools in the former Yugoslavia shortly before distribution to children (Buzina, personal communication). The children liked the slightly sour taste. Ryffel (Roche, personal communication) stated that vitamin C can be added to bottled water and is already the case with soft drinks and fruit juices. As an alternative to supplementation with vitamin C tablets in the former Yugoslavia, orange juice powder enriched to provide 350 mg of vitamin C per 100 g was distributed in the general ration. At the household/individual level, the powder was added to drinking-water.

Returning to refugee situations, especially in Africa, if vitamin C is to be added to large water tanks, several issues will have to be investigated:

- What can be done to overcome the degradation of vitamin C in chlorinated water?
- When would it be feasible to add vitamin C powder to water tanks and how soon should the water be consumed?
- How is the water distributed from the main tanks to the household? Should metal pipes or taps be used?
- How is the water stored at the household level?
- How much of the water is consumed and how much is used for other purposes, e.g. washing?
- How much vitamin C is left after the water has been boiled or used for cooking?
- How acceptable is the “new substance” in the water, from a psychological standpoint as well as in terms of taste?

Water fortification could also take place at the community or household level depending on how camps are organized and on the motivation of refugees.

Vitamin C powder added to water would have to be mixed well to ensure that it is adequately dissolved. Although adding plain effervescent vitamin C tablets to water would not require mixing, the major drawback is that tablets are highly sensitive to humidity; once damp they do not mix well in water. Effervescent tablets are available on the European market packed in aluminium foil and in aluminium or plastic tubes of about 10 tablets. Larger quantities could be packed in plastic. Lastly, effervescent tablets cost more than plain vitamin C powder.

Fortification of dried skimmed milk (DSM)

DSM can be an appropriate vehicle for vitamin C fortification in settings where it is distributed in the general ration, e.g. among pastoral nomad populations. In 1987, the Refugee Health Unit, Somalia, recommended that DSM be fortified with vitamin C since DSM is rarely cooked for very long and thus vitamin C loss during food preparation is limited. A number of laboratory analyses have been done on the retention of vitamin C in fortified DSM with encouraging results.

However, in other non-nomadic settings, the policy is not to distribute DSM in the general ration but to distribute it only in supplementary feeding centres in a cereal mix. In such cases other vehicles for vitamin C fortification will be required to reach those refugees most at risk of scurvy.

Germination

As mentioned above, in times of drought and famine, when fresh vegetables are not available, vitamin C can be obtained by germinating pulses or cereals. Davidson and Passmore (1986) have described as follows a frequently used recipe that has prevented many cases of scurvy in India:

> *A sufficient quantity of whole (unsplit) dhal or gram (say 1 ½ to 2 oz per man) is soaked in water for 12 to 21 hours. A container big enough to allow for expansion and holding sufficient water should be used. Then pour off the water, remove the grains and spread on a damp blanket in a layer thin enough to allow access of air, and cover with another damp blanket. Keep the blankets damp by sprinkling with water. In a few hours small shoots will appear, and when these are ½ to 1 inch long the process is complete. Vitamin C content is maximal after about 30 hours of germination. Pulses normally contain little or no ascorbic acid. One ounce (30 g) of dried pulse may on germination yield 9 to 15 mg of the vitamin, an amount sufficient to prevent scurvy.*

Carpenter (1986) reported on Russians sprouting beans and peas during World War II. After 2 days of germination, a vitamin C content of 35–40 mg per 100 g of starting material was achieved. By comparison, 100–150 g of lemons would have to be squeezed to obtain the same quantity of vitamin C from juice. However, cooking reduces vitamin C content drastically and drying and subsequent storage reduces it almost to zero. Germination would thus have to take place at the community or household level rather than centrally. Several major issues need to be considered:

- Is the practice of germination culturally acceptable?
- How are germinated pulses/cereals prepared before consumption?
- Are germinated pulses/cereals consumed by all members of the family?

Also, since germinated pulses tend to be bitter, this intervention might be successful in some refugee populations and not in others. For example, it has been successfully used by refugees in Thailand, whereas preliminary studies in Somalia have shown difficulties with acceptance.

Other interventions

Another option for increasing the vitamin C intake of refugees would be to improve their diet by adding commodities to the basic ration. Tomato paste is readily accepted by many refugee populations in Africa, tomato sauce being a regular item of the usual diet. However, the stability of vitamin C in canned tomato paste is questionable. Due to the high acidity of tomatoes the metal can usually starts to corrode. Metal ions could react with the vitamin and destroy (oxidise) it (Roche, personal communication). The stability of the vitamin would therefore depend on the material used to pack the tomato paste. Vitamin C losses during cooking would have to be looked into, as well as the feasibility of timely delivery, distribution, availability and cost.

Herbs and spices are good sources of vitamin C and significantly increase nutrient intake by enhancing the flavour of prepared foods. Dried peppers can have a vitamin C content as high as 180 mg per 100 g, dried sweet peppers 90 mg per 100 g, and dried red peppers 12 mg per 100 g (FAO/WHO, 1970). Once again, losses prior to consumption have to be investigated and problems regarding logistics, availability and cost taken into consideration.

Various fortified "new food" options for use by all members of a household as part of the total diet include chocolate and candy bars, sweets, dry instant-soup mixes, and condiments. Their cultural acceptability by all age groups, costs and related logistics should be determined in advance. Since most of the items suggested as alternative sources of vitamin C are products of fairly sophisticated markets, they may well not be consumed by target populations. A strong educational component emphasizing the importance of their consumption would thus be required to help ensure the success of any such intervention.

Costs

The cost of various commodities/interventions to improve the vitamin C intake of refugees and other populations affected by major emergencies is listed in Table 2 in the annex. The costs include insurance and freight. Table 3 in the annex attempts to compare the costs of fortified, milled cereal (maize), non-milled, non-fortified cereal and blended cereal-legume food (CSB). The expected costs of milling are substantially greater than the cost of adding micronutrients. The cost of the fortification and the milling of the whole cereal ration and the cost of adding 100 g blended cereal-legume food (CSB) to the ration are similar. The cost of the micronutrients (including vitamin C) is not the issue; milling, which is essential for the fortification process of, for example, maize, adds about 60% to the cost. Additional costs are associated with the processing and packaging of the milled product, and the quality control of its fortification.

The extra cost for increasing the general ration by 10% is comparable to that of adding 30 g of blended cereal-legume food to the daily ration. However, at least 120 g of cereal-legume mix equivalent to 48 mg vitamin C per ration (100 g CSB manufactured by Protein Grain Products International, USA contains 40 mg vitamin C) would be necessary to cover the daily recommended requirement of 28 mg vitamin C per person in a mixed population taking into account the expected losses of vitamin C during storage and during meal preparation. Including 120 g of cereal-legume blend to the general ration would be four times more costly than increasing the general ration by 10%. However, if the product was fortified with higher levels of vitamin C e.g. 120 mg vitamin C/100 g, the cost of blended cereal-legume food as an intervention to prevent scurvy would be almost equivalent to a 10% increase in ration.

Vitamin C tablets are not expensive compared to other commodities but the cost-effectiveness of supplementation with vitamin C tablets is liable to be low because of poor coverage, and non-sustainability of this intervention over time. The cost of tomato paste, calculated at 100 g per person per day, is very high; nevertheless, it might be one of the few ways to increase vitamin C in the ration in certain situations, over the short term. The cost would be comparable to that of fresh vegetables distributed in the general ration in Nepal. The cheapest fortified special food seems to be orange juice powder, which is known to be popular. A major drawback, however is that the powder tends to be consumed in amounts well beyond the daily portion, and hence the supply is rapidly exhausted.

The cost of fortifying sugar and water depends on the degree of fortification, which in turn depends on the estimated losses of vitamin C. One thousand grams of vitamin C powder costs approximately US$ 17/-, which translates to only US $0.0005 for a 30 mg daily supplement, not including distribution.

Conclusions and recommendations

Widespread deficiencies of micronutrients, e.g. vitamin A, iron, iodine, niacin, thiamin and vitamin C, frequently occur among refugee populations affected by major emergencies. It is difficult to meet micronutrient requirements through the standard emergency ration of cereals, beans and oil. This is particularly true of vitamin C, which is mainly found in fresh vegetables and fruit, and which is quite unstable in foods, especially when exposed to air, metallic surfaces, light or high temperatures. Refugees who are wholly dependent on food aid often consume inadequate levels of vitamin C, and several refugee populations have developed scurvy in the past decade—a disease that was formerly mainly associated with sea voyages and long naval expeditions between the 15th and 19th centuries. Scurvy is also prone to occur in drought-and-famine affected populations where fresh vegetables and fruits are scarce.

Severe vitamin C deficiency causes scurvy, a disease that manifests itself 2-3 months after consuming a diet lacking in vitamin C. Frank scurvy in adults is preceded by a period of latent scurvy, the symptoms of which include lassitude, weakness and irritability; vague dull aching pains in the muscles or joints of the legs and feet; and weight loss. Scurvy in adults results in internal haemorrhages, swollen joints, swollen bleeding gums, and peripheral oedema, with impaired work capacity. In infants, scurvy leads to irritability, tenderness of the legs, and pseudo paralysis, usually involving the lower extremities. Scurvy in any age group causes impaired resistance to infections and internal haemorrhages can be fatal.

Even a single case of clinical scurvy seen in a population reflects a public health problem and calls for a full nutritional assessment using biochemical methods to assess the vitamin C deficiency in the population. It is difficult to clinically define scurvy and very few people in the field have been adequately trained to be able to recognize scurvy correctly.

The development and application of a strategy for the maintenance of adequate vitamin C status in emergency-affected populations has beneficial implications over and above the elimination of scurvy. Vitamin C also promotes the absorption of iron and therefore helps to reduce the incidence of anaemia that is usually highly prevalent in such populations. The benefits of an improvement in iron status include reduced morbidity, improved physical work output and improved learning capacity.

There is no single universal solution to the problem of scurvy and not all interventions to prevent scurvy are feasible in every emergency setting. The principal way of addressing vitamin C deficiency is by improving the diet. Securing an adequate diet for large emergency-affected populations can be a problem especially in the initial phase of a relief operation. Distribution of fortified foods is an important way to secure adequate vitamin C intakes of a population where natural sources of vitamin C are lacking. Table 10 summarises several of the options for interventions to prevent or control vitamin C deficiency during an emergency. The figure in Annex 3 outlines the assessment protocol for the prevention of scurvy from the initiation to establishment phases of an emergency funding operation.

Table 10. Options for the prevention of vitamin C deficiency in an emergency

A. Local production of fruits/vegetables easy	
	***Fruits/vegetables immediately available*:**
1.	Add some fruits/vegetables to the ration
2.	Encourage barter or purchase by providing 10% extra ration
	***Fruits and vegetables not immediately available*:**
3.	Encourage household food production by providing necessary inputs
B. Local production of fruits/vegetables not easy	
	Provision of commodities fortified with vitamin C:
4.	Fortified cereal flour or fortified sugar
5.	Fortified cereal/legume blended food (120mg vitamin C per ration)
6.	Other vitamin C-rich foods e.g. fortified tomato paste, orange juice powder
	Provision of vitamin C supplements:
7.	Distribution of vitamin C tablets at least weekly

Primary strategies

Natural sources of vitamin C

The following approach is to be considered ***where vegetables, tubers and fruits can easily be produced or procured locally:***

C **Promote and support household production of fruits, vegetables and tubers.** The local cultivation of vegetables such as tomatoes, peppers, onions and leafy greens and tubers such as potatoes and sweet potatoes should be strongly promoted from the beginning as a long term strategy. Horticultural materials, water, and expertise in this area needs to be provided where and when feasible. Fruits, vegetables and tubers contribute useful amounts of iron and carotene as well as vitamin C. This approach should also encourage better dietary patterns on a long-term basis. The drawbacks are often poor environmental conditions e.g. lack of access to good quality land and adequate regular water supply, and even under optimal conditions it may take 2–3 months for the natural sources of vitamin C to be ready for consumption. There is therefore a need for an alternative intervention strategy to ensure adequate vitamin C intakes during the initial 2–3 months of an emergency.

In situations ***where vegetables, tubers and fruits can be easily produced locally and are already available on the market***:

- **Distribute fruits, vegetables and tubers**. The distribution of vitamin C-rich foods e.g. fruits, vegetables and tubers, as part of the general ration should be one of the first options where feasible. It is likely to be a temporary measure but is relatively costly.

- **Increase the general ration by about 10% and encourage the sale and/or barter of a portion of the ration in exchange for locally available fruits and vegetables.** The most effective and least costly way of enabling emergency-affected populations to cover their vitamin C and other micronutrient requirements is probably to increase the general ration by about 10% above the basic requirements. Several studies have shown that the larger the ration provided, the greater is the trading of foodstuff, resulting in greater consumption of fruit and vegetables. Sale and/or barter of a portion of the ration should be encouraged where markets are available. The same approach is advocated for those seeking to alleviate economic hardship and dependency of severely affected populations and the lack of resources to meet other basic needs. One of the major constraints for increasing the ration, say, by 10%, is the availability of sufficient food resources, since in the field, refugees frequently do not receive sufficient quantities of even the general ration.

Vitamin C-fortified foods

In situations ***where vegetables, tubers and fruits cannot be easily produced locally,*** foods fortified with vitamin C need to be distributed. The following options are to be considered for the distribution of vitamin C fortified foods to any emergency affected population:

- **Distribute fortified blended cereal-legume foods in the general ration.** Blended cereal-legume foods may be suitable foods for distribution during the initial emergency phase of an operation. It is important to ensure that the daily ration contains about 120 mg vitamin C per day, and provided all family members of the at risk population consume the food prepared with the blend.

- **Distribute other adequately fortified foods e.g. fortified cereal flour or fortified sugar in the general ration.** Milled cereals and sugar are from a technical standpoint the most appropriate commodities of the general ration for fortification with vitamin C. The cost to fortify a product is not high, however, additional costs are incurred with the processing (milling etc.) and packaging of the fortified product as well as quality control of the product. 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.

- **Distribute fortified vitamin C–rich foods e.g. tomato paste, orange juice powder.** Special foods rich in vitamin C or fortified with the vitamin e.g. orange juice powder or any powdered drink for reconstitution, dried fortified peppers, fortified tomato paste or powder, fortified dry soup mixes or condiments, or fortified candy bars, are relatively expensive and are unlikely to be a serious option except perhaps in special situations. Of these, enriched orange juice powder is by far the least expensive; and at the same time widely acceptable. Further operational research on its use is desirable; particularly as a short-term measure, and for consumption once or twice weekly.

Vitamin C supplements

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

C **Supplementation with weekly vitamin C tablets.** Distribution of vitamin C tablets weekly under supervision may be one of the options to prevent scurvy in the initial phase of an emergency. Ideally vitamin C tablets should be distributed for daily supplementation but it is difficult to maintain consumption consistently over long periods and to achieve a good coverage of the affected population. The possibility of good outcome by weekly dosage as an intervention deserves further field investigation

The interventions to prevent scurvy 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, or possibly locally procured fruits and vegetables, 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, germination may be options during the *establishment phase* of an operation. Longer-term solutions to prevent scurvy should always aim at the self-sufficiency of emergency-affected households which includes horticultural activities as well as local trading.

Supporting strategies

C **Nutrition education.** Nutrition education should be seen as an essential component of any intervention to prevent scurvy. 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 which could be produced or purchased, and help in introducing unfamiliar imported food aid. See the annex for examples of some important messages related to prevention of scurvy. Any message, of course, has to be adapted to the location and situation where it is disseminated.

C **Training of field workers**. Improving the skills of field workers in the clinical assessment and management of scurvy 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 vitamin C deficiency in emergency-affected populations where there is the likelihood of an outbreak or risk of scurvy.

C **Establishment or identification of facility for biochemical assessment of scurvy.** Currently there are no field-friendly methods available for the biochemical assessment of vitamin C deficiency. It is therefore neccessary to identify facilities at the national level where the vitamin C levels of blood samples can be determined rapidly and with precision.

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Annex 1

Table A Phases of refugee feeding operations and prevention of scurvy

Table B Costs of various commodities

Table C Cost comparisons

Table D Some nutrition education messages that could help prevent scurvy in refugees

Table E Analytical values of some traditional antiscorbutics used by sailors in the 18th century

Table F Analytical values for the vitamin C content of items in traditional Eskimo diets

Table G Vitamin C content of some uncooked food

Table H Intake levels of ascorbic acid in various parts of the world

Table I Vitamin C losses in processing and preparing food

Table A. Phases of refugee feeding operations and possible sources of vitamin C

Phase	Characteristics	Food source	Vitamin C source
Initiation/ 3-6 months	initial request for help filed	may be local or borrowing from other programmes	fortified food aid; vitamin C tablets; vitamin C-rich commodities; where feasible, locally procured fruits and vegetables; increased general ration
Establishment/ 6 months - 2 years	refugees dependent on food aid/minimal personal buying power	imported food aid	fortified food aid; where feasible locally procured fruits and vegetables; increased general ration; where feasible, germinated cereals/pulses; home gardens; local trading for vitamin C-rich foods
Protracted Refugee Operation/ >2 years	efforts to develop inde-pendence and personal economic resource Employment pro-grammes maintained.	depending on local conditions, may involve tar-geting of food aid on basis of need	home gardens; local trading for vitamin C-rich foods

Note:
1. The first two phases are critical for the development of scurvy
2. Table is adapted from Hansch (1995)

Table B. Costs of various commoditites

Commodity	1m person days (USD)	Person/day (USD)
Total ration[1]	200 000	0.200
Ration with 30 g blended food[1]	215 000	0.215
Ration with 60 g blended food	230 000	0.230
Total ration +10%	220 000	0.220
Cereal (maize) <u>not</u> milled[2]	100 825	0.101
Cereal milled[2]	135 625	0.136
Cereal fortified* + milled[2]	150 025	0.150
Cereal (3/4 of cereal ration) + CSB (1/4 of cereal ration)[2]	147 125	0.147
Tablets (vitamin C @ 250 mg)[3]	1 170	0.001
Tomato paste @100 g/day[4]	96 000	0.096
Orange juice powder[3] (reconstituted drink)	11 770	0.012
Fresh vegetables[4]**	100 000	0.100

[1] Source: Machakos Workshop Report (1995)
[2] Source: Beaton (1995)
[3] Source: Toole (1995)
[4] Source: UNHCR

* Fortified with micro nutrients (including vitamin C)
** Example Nepal (1993)

Table C. Cost comparisons

Commodity	I m person days (US$)	person/day (US$)
Blended foods increase 30 g to 60 g per day	15 000	0.015
Ration 10% increase (without blended foods)	20 000	0.020
Cereal milled and fortified compared to unmilled and unfortified	50 800	0.051
Cereal milled and fortified compared to milled and unfortified	14 400	0.014
Cereal milled and CSB (1/4 of cereal ration)* compared to unmilled, unfortified cereal ration	47 700	0.048
Cereal milled and CSB (1/4 of cereal ration)* compared to milled, unfortified cereal ration	11 500	0.012

*100 g CSB daily would be necessary in the general ration to provide missing micro nutrients
e.g. vitamin C in blended foods 30-40 mg /100 g, RDA 30 mg

Table D. Some nutrition education messages that could prevent scurvy

Food storage and preparation

- Grow tomatoes, potatoes, onions, etc. on any available land and use waste water.
- *Do not store germinated pulses/grains.
- Store fresh vegetables and fruit for as short a time as possible.

Food production and consumption

- Vegetables should not be cut into small pieces before washing and cooking.
- Cook vegetables in minimum amount of water and also consume water.
- Cook food for as short a time as possible.
- Cover pot with lid while cooking to reduce cooking time.
- Eat food soon after cooking. Do not store cooked food.
- Cook blended food for not longer than 10 minutes.
- Blended food is good for the whole family, not only for infants.
- Eat as much fruit and vegetables as available.
- *Eat the sprouts and the shoots after germination

Medication

- *Take the vitamin C tablets regularly to prevent scurvy and death.

*Some examples of messages related to specific interventions.

Table E. Analytical values for some of the sailors' traditional antiscorbutics in the 18th century

	Ascorbic acid (mg/100g or /100 ml for liquids)
Cloud berries	80
Cranberries	5-10
Gooseberries, fresh	60-65
Gooseberries, preserved (as recommended by Lind)	0
Apple cider (fresh,unpasteurized)	4-5
Scurvy grass (leaves and buds)	200
Spruce pine needles	65-200
Spruce (leaves and young shoots)	30-270
Spruce (fresh aqueous infusion)	14-100
Spruce (fermented aqueous infusion)	<0.5
Freshly sprouted barley seed	30-100
Malt, dried & powdered	10
Cloud berries	80
Cranberries	5-10
Gooseberries, fresh	60-65
Gooseberries, preserved (as recommended by Lind)	0
Apple cider (fresh,unpasteurized)	4-5
Scurvy grass (leaves and buds)	200
Spruce pine needles	65-200
Spruce (leaves and young shoots)	30-270
Spruce (fresh aqueous infusion)	14-100
Spruce (fermented aqueous infusion)	<0.5

Source: Carpenter, 1986

Table F. Analytical values for the vitamin c content in mg/100 g of items in traditional inuit diets

	Raw	Lightly boiled
Seal flesh	0.5-3	0.5-2.5
Seal liver	18-35	14-30
Whale skin (narwhal)	18	N.D.
Whale skin (Beluga)	35	N.D.
Blubber (Beluga)	5	N.D.
Animal flesh, raw (caribou, musk ox,	0.8-1.8	0.5
Fish flesh (cod, char)	0.5-2	N.D.
Cod roe	44	N.D.
Bird flesh, raw	1-2	0.3-1
Licorice root	21	4
Mountain sorrel	36	5
Angelica	14	-

Source: Hoppner et al. 1978

Table G. Vitamin C contents of some uncooked foods

	Vitamin C mg/100 g		Vitamin C mg/100 g
Fruits:		**Vegetables**:	
peach	8	amaranth leaves	88
banana	13	beans, peas	10-30
cherry	8	broccoli	90-150
grapefruit	43	cabbage	30-60
guava	160	carrot	5-10
hawthorne berries	160-800	cauliflower	60-80
lime	27	garlic	12
mango		dark-green-leafy vegetables	100-150
ripe	4875	kale	120-180
unripe		leek	15-30
melons	13-33	onion	10-30
orange, lemon	50	parsley	170
papaya	64	pepper	125-200
pineapple	40	spinach	50-90
tangerine	30	tomato	24
raspberry	18-25		
rose hips	1000	**Cereals**:	
strawberry	40-90	millet, rice, wheat, maize	0
Animal products:		**Tubers**:	
meats	0-2	cassava	36
liver, kidney	10-40	sweet potato	23
milk, cow	1-2	potato	36462
milk, human + camel	3-6		

Source: FAO. Food composition tables. Minerals and vitamins for international use. Rome, 1954.

Table H. Intake levels of ascorbic acid in various parts of the world, in mg per person per day

Region	Extreme range [a)]	Majority range [b)]	Comments
Africa	5-375	-	Low values for cereal and millet diets. High values for diets based on cassava, yams, etc.
Asia, including the Far East	10-150	25-70	Higher values are for China (Taiwan), where diets include a greater proportion of vegetables and fruits. Low values are for millet and rice diets in India and East Pakistan respectively.
Latin America	10-110	10-50	
Near East	5-90	10-50	
Europe	50-130	50-130	
USA	-	100	

a) Average lowest and highest per capita intakes reported in surveys

b) Lowest and highest per capita intakes of more than 80% of the population reported in surveys

Table I. Vitamin C losses in the processing and preparation of food

	Ascorbic acid (% remaining)
Potatoes	
fresh dug main crop	30 mg/100 g
boiled, peeled	50-70% raw
in jacket, baked	80% raw value
Milk	
whole raw	2.0 mg/100 g
pasteurized	75% raw value
Cabbage	
raw	60 mg/100 g
cooked	33% raw value
Frozen vegetables	75% raw value
Canned vegetables	85-40% raw value

Source: Marks, 1975

Annex 2

Research requirements

Regarding the feasibility of interventions, that include fortified commodities, there are operational considerations that need to be addressed as well as operational research that would need to be carried out. Some of the major issues related to interventions to prevent scurvy involving fortification, are listed below. Some of these have been addressed recently with varying degrees of success.

1. FORTIFIED BLENDED CEREAL-LEGUME FOODS

- What are the losses of vitamin C during transportation, storage, and meal preparation and what is the retention of vitamin C just before consumption?
- What fortification level and ration size is necessary to ensure adequate intake of vitamin C in emergency-affected populations where other sources of vitamin C are not available?

2. FORTIFIED CEREALS (MILLED AND UNMILLED)

- What are the losses of vitamin C during transportation, storage, and meal preparation and what is the retention of vitamin C just before consumption?
- Where would fortification take place? What is the feasibility of fortification at national, local/community level?
- What would fortification levels have to be to ensure sufficient intake of vitamin C?

3. FORTIFIED SUGAR

- Stability of vitamin C in sugar from site of fortification to the household level, and what losses occur during consumption?
- How does humidity affect the stability of vitamin C in sugar?
- What is the usage of sugar at household level and how much is consumed by whom, in emergency situations?

4. COMPLEMENTARY PRODUCTS; orange juice powder, dried pepper powder, tomato paste, dry soup mixes, condiments, rich in vitamin C

- Stability of vitamin C in the commodity?
- When is the commodity added to the meal and what is the retention of vitamin C just before consumption?

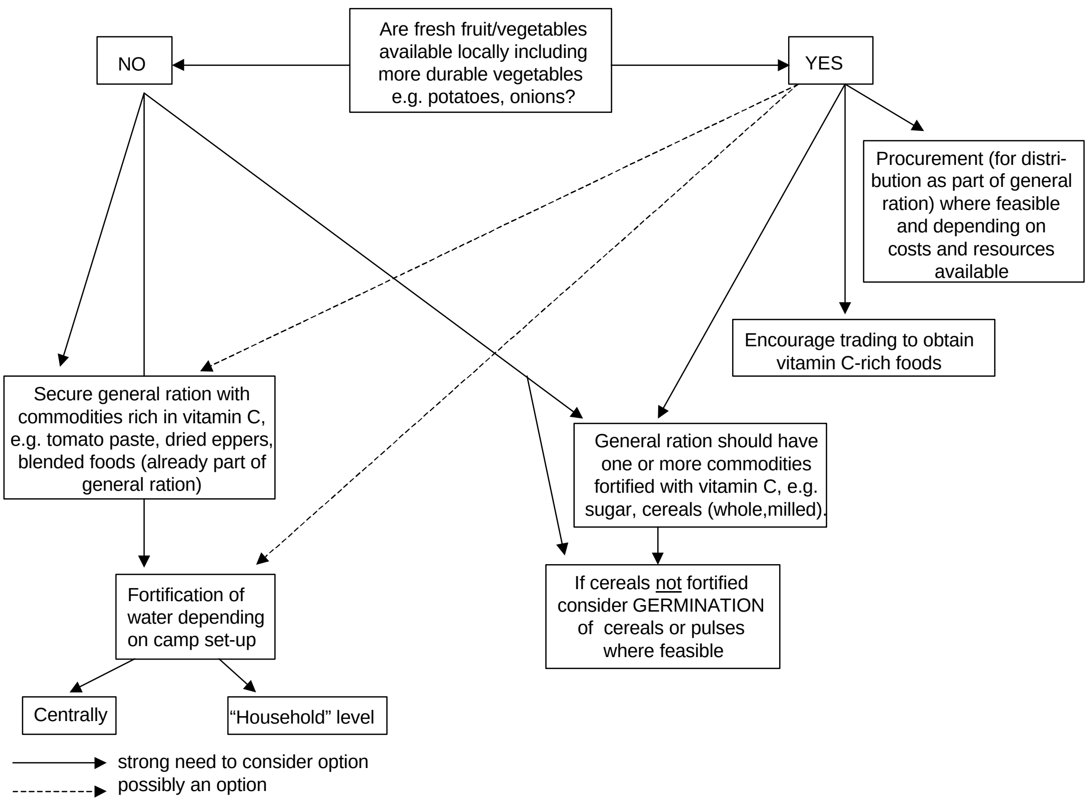
- Who consumes meals prepared with the commodity and how often is it used?
- Is it readily available for distribution?
- Shelf life of the commodity?
- Does it have a high market value in the area?

5. FORTIFYING WATER WITH VITAMIN C

- What can be done to overcome the degradation of vitamin C by chlorine?
- How is the water stored at the household level?
- Is it feasible to fortify water at the "household" level before consumption?
- What must the level of fortification be for acceptable levels of vitamin C to be consumed?
- Is the taste acceptable?

Annex 3

Figure outlining the assessment protocol for prevention of scurvy during the initiation and up to the establishment phases of an emergency feeding operation.



Note:

1. Home gardens should be established where and when feasible (-distribution of seeds and education.)
2. Nutrition education should be a component of every intervention
3. Normally unused foods that might be exploited (roots, leaves, wild fruit) should not be forgotten. They might be able to contribute substantially to vitamin C intake in particular periods in certain areas