

# The young child nutrition and malnutrition

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## Chapter 1.

### The role of weaning foods in infant feeding

From birth to the age of 4 months, all the infant's nutritional needs are perfectly met by breast milk. On the other hand, between 4 and 6 months breast milk is no longer sufficient to fully cover energy and protein requirements. This is the so-called weaning period during which a breast milk supplement must be provided in the form of a runny pap containing a balanced mixture of the nutritional elements necessary for the child's healthy growth. Later, from the age of 1 year onwards, the child will feed itself from the family meal. To determine the ideal composition of the weaning food, it is of course necessary to have an accurate picture of how the child's different needs evolve as it grows and develops.

#### 1.1 Nutritional requirements of the young child

##### 1.1.1 Energy requirements

Between birth and the age of 4 months the infant doubles in weight (which rises from 3.5kg to 7kg), this requires a high energy input. This energy requirement is expressed in calories, or more precisely in kilocalories (kcal) per day. Table 1 shows the progression of calorie requirements with age and the recommended daily quantities of proteins, iron and Vitamin A.

Table 1. Nutrient intake recommended for young children (FAO, WHO)

Age	3-6 months	6-9 months	9-12 months	1-2 years	2-3 years	3-5 years
Weight (kg)	7	8.5	9.5	11	13.5	16.5
Energy (kcal/day)	700	810	950	1150	1350	1550
Proteins (g/day)	17	20	20	20	23	26
Vitamin A (µg/day)	300	300	250	250	250	
Iron (mg/day)	7	7	7	7	7	

At 4 months, the baby's calorie requirements are estimated at 700kcal/day. At that age an infant takes about 800ml of breast milk per day in 5-6 feeds (its stomach size limits the volume at each feed). These 800ml of milk provide about 560kcal. Hence the need to give the child a supplement of 140 kcal each day, which is the role of the weaning pap.

##### 1.1.2 Protein requirements

The quantity of protein required is about 20g/day between 6 months and 3 years. As an indication, the mother who gives 800ml of milk provides her child with just 8g of protein a day. The weaning pap thus has to supply the child with the missing 12g of protein. Ideally, the amino acid composition of these supplementary proteins should be identical to that of breast milk, i.e. contain the same proportions of the nine essential amino acids (including lysine,

threonine and tryptophan). These amino acids are called essential because the child's organism is incapable of synthesising them and they have to come from the food. Some proteins of animal origin have an amino acid composition very close to that of breast milk. These are the proteins in animal milk (cow, goat) and in meat or eggs, which are generally out of reach for mothers in underprivileged settings because they are "expensive" proteins.

Fortunately, it is possible to reconstitute a mixture of proteins with a satisfactory composition for the child's needs by mixing a cereal flour (wheat, rice, maize, millet, etc.) with a flour of legumes (soya, beans, niébé). The amino acids missing from the cereal proteins are then supplemented by the amino acids present in the legumes. Because of its amino acid composition, *spirulina* is also an excellent source of protein for the child: a mixture of *spirulina* and cereal flour provides a combination of essential amino acids that is very digestible, readily assimilated and well adapted to the young child's requirements. If the child takes two portions of millet pap per day, the addition of 4g of dried *spirulina* to each millet portion is sufficient to meet its essential amino acid requirements.

### 1.1.3 Vitamin requirements

Among the 12 Vitamins necessary for the child's organism, some are particularly indispensable a very young age:

- Vitamin A, which protects against infections and safeguards the integrity of the skin and mucous membranes;
- Vitamin D, which fosters bone growth and protects against rickets;
- Vitamin C, which protects against scurvy;
- Vitamins in group B - B1, B2, B6 and PP - which help in the utilization of the energy contained in foods;
- Foliates and Vitamin B12, which have a role in the production of red cells.

Emphasis should be placed on Vitamin A, because in some parts of the world Vitamin A deficiency is a real public health problem. Vitamin A is important in sight (it permits night vision), the protection of the skin and mucous membranes (digestive and respiratory systems, etc.) and especially the conjunctiva of the eye and cornea, which it protects against infections. Vitamin A deficiency is known as xerophthalmia and is discussed in a later chapter. It occurs in foods in two forms: retinol or true Vitamin A, present in milk, animal liver, eggs, etc.; and in the form of precursors or proVitamin A, which are the carotenoids of the plant world present in leafy vegetables, fruits, palm oil, and also *spirulina*, which contains appreciable quantities.

### 1.1.4 Mineral requirements

Among the numerous minerals essential for child development - calcium, magnesium, fluorine, zinc, selenium, iodine, etc. - deficiency of one is particularly widespread in the world, and that is **iron**. From birth to the age of 6 months, the child's iron requirements are supplied by breast milk, which provides iron in an well-absorbed form. After 6 months it becomes difficult for the child to obtain the quantities of iron necessary for the production of its haemoglobin in a typical developing country diet, which is why so many of them are anaemic. *Spirulina* can be a valuable source of iron for the child, this question will be examined in more detail subsequently.

Another trace element that is often deficient is **zinc**. The lack of zinc causes growth retardation. It is possible to enrich the zinc content of *spirulina* by adjusting the composition of the culture medium and thus to meet the whole of the child's zinc requirements.

In summary, for harmonious growth the child needs many nutrients: energy-providing nutrients (sugars or glucides, fats or lipids), building nutrients (proteins) and protective nutrients (Vitamins and minerals). It should be emphasised that it is necessary to provide the nutrients simultaneously, that is, they all need to be present at the time of the meal, for if one of them is deficient in the portion, the utilisation of all the other nutrients by the organism will be hindered. Let us see how these are provided for the child in the developing country context.

## 1.2 Traditional feeding of the young child in developing countries

### 1.2.1 Maternal breast feeding

Traditionally the infant is breast fed for a period that varies according to the culture but often lasts more than a year. As already noted, breast milk offers many advantages: it provides the infant with all the essential elements in balanced proportions, and protects it against infections thanks to the elements (immunoglobulins, white corpuscles, lactoferrin) it contains. As indicated elsewhere, it is a food that is sterile, ready to use and inexpensive. It covers the entire needs of a child during the first months of life.

However, after the fourth month, a strict diet of milk no longer covers the infant's requirements, particularly in energy and iron. There is a risk that protein-energy malnutrition or iron-deficiency anaemia will appear. Thus it is necessary to introduce a supplementary food in the form of a pap.

### 1.2.2 The weaning period

The mother, while continuing to breastfeed, is aware of the need to give the child a light pap prepared from local foods (millet, maize or manioc flour, etc.) diluted in water. Then, after several months, a semi-solid purée often coming from the family meal, with sauce or sugar added, which she gives the child once or twice a day. This pap is often prepared in advance and kept in poor hygienic conditions. That is why so-called "weaning" diarrhoea is so

common in tropical countries.

This pap is most frequently based on cereals (rice, millet, sorghum, maize), roots (manioc) or tubers (yams) depending on the region. These paps are certainly rich in carbohydrates, yet their energy content is notoriously inadequate: a millet pap contains only 40-75kcal per 100g while breast milk provides 72kcal per 100g. Moreover, their protein content is poor. These two factors - bacteriological contamination and mediocre nutritional value of the weaning food - explain why malnutrition is so common between 6 months and 2 years of age.

Moreover, in some societies, for example in Africa, weaning is often brutally sudden: it happens from one day to the next. Because the mother is pregnant or thinks she is pregnant, the child is taken from the mother's breast and passed immediately to another member of the family. The child is disoriented, shows behavioural difficulties and obstinately refuses to feed itself, which only exacerbates an already precarious nutritional situation.

### 1.2.3 Feeding from the family meal

From about 2 years of age, the child eats only from the family meal, which is prepared twice - or even just once - a day. It receives an apparently voluminous portion of a family meal that is often very spicy, with low energy value and containing few fats and proteins. In these conditions, the food intake meets barely 60%-70% of calorie requirements and 80%-90% of protein requirements. Thus all the elements are gathered for a state of malnutrition to gain a footing or for pre-existing malnutrition to get worse.

## 1.3 The growth of the child on a traditional diet

The result of the above is that the growth and development of children living in developing countries goes through distinct stages. During the first months, say the first 6 months, the child is breast-fed, its growth is normal, and it is lively and cheerful. After 6 months, when weaning food is introduced, the weight gain dips. At 12 months its weight is rarely more than 9kg. From 12 to 18 months, the weight may evolve in any direction, from stagnating to falling back. This evolution depends on the quantity of breast milk, and above all on the nutritional value of the supplementary food.

## Chapter 1 References

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# Chapter 2

## The different forms of child malnutrition

A child receiving too few nutrients in its daily food is exposed to different forms of malnutrition. If the deficiency relates principally to energy and protein intake, one speaks of protein-energy or protein-calorie malnutrition (PEM). If the deficiency relates chiefly to iron, one speaks of nutritional anaemia, and if it relates mainly to Vitamin A the symptoms are called xerophthalmia. It is unfortunately not unusual for a child to show simultaneous signs, to different degrees, of all three forms of malnutrition. In addition, it is common for a child living in a developing country to be affected by chronic energy under-nutrition. This is characterised by retarded growth and development, and increased susceptibility to infection.

### 2.1 Acute protein-energy malnutrition

It is estimated that in the world 20 million children less than 5 years are affected by acute malnutrition in the form of kwashiorkor or marasmus. This is called *acute* malnutrition because it unveils itself suddenly and entails serious and often fatal complications if not appropriately treated. It particularly affects children aged from 1 year (after weaning) to 5 years.

Past that age, overt acute malnutrition is less common and replaced by growth retardation, which is widely prevalent

among children from underprivileged socio-economic environments.

### 2.1.1 Sequence of factors leading to PEM

PEM results from the interaction of several factors, including:

- (1) An *insufficient diet* quantitatively and qualitatively.
- (2) *Repeated infections*: diarrhoea, respiratory infections, and measles. These infections create a state of malnutrition because they increase the child's requirements (fever) and reduce the absorption of nutrients in the digestive system (diarrhoea). It should be remembered that on average a child born in a developing country has three episodes of fever or diarrhoea every month during its first two years.

To take the diet first, the limiting factor most often incriminated in infants is the inadequate energy intake; after that comes a shortfall in protein intake. Thus nearly 25% of children aged 3-5 years do not consume the 1100kcal they would need. Their calorie deficit is about 440kcal per day. As to the deficit in protein intake, this relates both to the quantity of proteins, which is insufficient, and their quality (through the lack of some so-called essential amino acids). On top of this deficit in energy and proteins, deficiencies in iron, Vitamin A and group B Vitamins often occur. The conjunction of these different factors entails disturbances in organ function and a slowdown in growth that is commonly known under the name of protein-energy malnutrition.

It is in the pre-school years, from 2 to 5 years of age, that malnutrition is the most marked, for the following reasons:

- (1) Nutrient requirements are very high in relation to the child's body weight when compared to those of older children.
- (2) The traditional paps offered (based on manioc, rice, etc.) are not sufficiently "nourishing"; they do not provide a high enough calorific density bearing in mind the volume of the child's stomach. Thus, to get the 1100kcal that represent its daily calorie requirements, a child aged 1-year would need to consume 900g of thick maize porridge (prepared from 310g of maize flour). As its stomach's volume is about 180ml, it would therefore have to be fed at least 5 times a day, whereas in fact its mother prepares the pap only twice a day, in the morning and evening.
- (3) At this age the child begins to explore the world. It comes into contact with people from outside its family environment and with strange foods; for that reason, it is increasingly exposed to sources of infection against which it has not yet any immune protection, hence the frequency of episodes of diarrhoea and fever. During each of these infectious episodes - which occur on average three times a month - it loses appetite and reduces its food intake, which is already insufficient in normal times. In addition, the protein intakes are often reduced in both quantity and quality.

A state of malnutrition progressively develops that is called "protein-calorie malnutrition" but in fact is comprehensive since the reduction in intake affects all nutrients. If nothing is done to halt this deterioration, marasmus or kwashiorkor appears. Marasmus is the most common form of severe malnutrition. The child seems to be nothing but skin and bones, muscular wasting is obvious, and subcutaneous fat has disappeared. This aspect of marasmus results from repeated episodes of diarrhoea and other infections, from maternal breast feeding continued too long without an adequate supplementary diet, and overall from too small a calorie and protein intake.

Kwashiorkor is less common and is found chiefly among children whose diet is particularly deficient in proteins. The child is infiltrated with oedema in the legs, its face is swollen and the skin cracked. The child is apathetic, showing little reaction to what is happening around it.

In practice, nutrition rehabilitation centres (NRCs) see many more intermediate forms, which include symptoms from both marasmus and kwashiorkor. Thus some kwashiorkors, after treatment has started and the oedemas dissipate, show the symptoms of marasmus. It should be added that the distinction between marasmus = energy deficiency + protein deficiency and kwashiorkor = deficiency in proteins alone corresponds poorly with what is seen in NRCs. It seems that it is the child's past history of infection that is in fact responsible for the establishment of one or the other form of malnutrition.

### 2.1.2 Detection of protein-energy malnutrition

There are several simple methods, applicable in any conditions, to monitor a child's growth and evaluate its nutritional status. This makes it possible to detect an incipient malnutrition and take the necessary measures in time. We shall confine ourselves to two of the simplest and most often used techniques, which are regular weighing and measurement of arm circumference. For other methods such as monitoring weight in relation to height and the use of a thinness diagram, the reader can consult the references at the end of this chapter.

- (1) Regular weighing:

If possible, children should be weighed every month during the first two years of life. The weight is recorded on a curve of weight in relation to age called the "Road to Health". UNICEF developed this graph from data collected in different populations and serves as an international reference. The upper limit of the Road to Health represents the mean weight observed at each age (month by month) in populations where there is no malnutrition. The lower limit represents the threshold beneath which malnutrition of the child should be suspected. A regular curve reflecting a regular and harmonious weight gain indicates that the child is properly fed. If the curve remains flat, i.e. if the child does not gain weight or - still more serious - if the curve is close to the lower limit of the Road to Health, the child is at risk of malnutrition.

The regular weighing of all the children in a community is the most reliable way of detecting malnutrition and the only one usable before the age of one year. However, it presupposes that the child is regularly presented by its mother at the dispensary or weighing sessions. Experience shows that unfortunately it is the children least at risk who are monitored most regularly.

For children who are seen occasionally, where monthly variations in weight cannot be estimated, their weight is compared with the lower limit of the curve: if it is below this threshold, the child must be considered *malnourished*. These values are shown in the first column of the table that follows. If the child's weight is lower than the values in the second column of the table, the child is considered *severely malnourished*.

Detection of malnutrition at a single weighing up to one year of age

Age of a child (months)	If the child weighs less than this weight, it is <i>malnourished</i> (*) (kg)	If the child weighs less than this weight, it is <i>severely malnourished</i> (**) (kg)
3	4	3.4
4	4.5	3.8
5	5	4.2
6	5.5	4.5
7	6	4.8
8	6.4	5.1
9	6.7	5.3
10	7	5.5
11	7.3	5.8
12	7.6	6.0

(\*) Values corresponding to the lower limit of the Road to Health.

(\*\*) Values corresponding to 60% of international standards.

(2) Measurement of arm circumference:

Between the ages of 1 and 5 years a child's arm circumference varies only slightly and reflects its nutritional status reasonably well. It is accepted that if the circumference is less than 13.5cm the child is malnourished and if it is less than 12.5cm the malnutrition is severe. This method is admittedly not very sensitive but nevertheless it is a good way of screening. Children detected by this method should be weighed, and it is essential to start a curve so that progress in the child's nutritional rehabilitation can be regularly monitored.

### 2.1.3 Management and treatment of PME

- Management of *moderate* malnutrition:

The treatment is based on (1) the diet and (2) the control of infections. It can and should be carried out by community health workers.

- (1) The diet: the mother should be advised to administer, 4-5 times a day, food enriched in calories (by adding oil) and enriched in proteins (by adding a protein source such as *spirulina* powder). The later also having the advantage of supplying Vitamin A and iron. Breast-feeding should continue. Health workers should monitor the child through regular home visits.
- (2) The control of infections: the mother should be told what measures to take in the event of fever, diarrhoea, and respiratory infections. Special attention should be paid to controlling dehydration during diarrhoea episodes by showing the mother how to prepare a sugar-saline rehydration solutions and to use packets of rehydration salts. Any infection should be treated quickly, in the knowledge that a malnourished child is not able to fight off infections by itself. A point should be made of stressing to the family the value of general hygienic measures to improve the environment.

Health workers should ensure by weighing the child regularly that these measures are properly applied and that the child resumes the "Road to Health".

- Management of *severe* malnutrition:

A child who presents with serious muscular wasting, whether or not associated with oedema, should be considered as a medical emergency, all the more so if it has diarrhoea, dehydration or an infection. The emergency treatment should be carried out under medical supervision, generally in a hospital setting, for a period of 2 weeks, after which the child is generally transferred to a nutrition rehabilitation centre. During all this period, the mother should stay with the child. The treatment of severe malnutrition is based on (1) the correction of possible dehydration, (2) the treatment of infections, and (3) nutritional rehabilitation through a diet rich in energy and proteins.

- (1) Correcting dehydration: if the child is ready to drink, it should be given small quantities of a rehydration solution containing potassium and bicarbonate of soda as well as sugar and salt. If it refuses to drink this

solution it should be administered by nasogastric tube.

- (2) The treatment of infections: antibiotics should be administered systematically, even in the absence of obvious clinical signs of infection, particularly if the child shows signs of infection.
- (3) Nutritional rehabilitation: severely malnourished children should receive food that is rich in good-quality proteins and very rich in energy. At the start of the treatment, when the child is not hungry this can only be achieved in practice with milk-oil-sugar mixtures. This mixture is administered either with a spoon or by tube various times a day.

After 4-5 days, the child feeds spontaneously and the mother can give it cereal paps enriched with oil and with protein by adding *spirulina* powder. When the infections have disappeared, the child has gained in weight, its general state is satisfactory and it has found its appetite again, and when the mother has learned what she should prepare for it, it can return home. But it should be carefully monitored for at least 6 months in order to prevent relapses.

#### 2.1.4 Growth retardation from chronic malnutrition

It is estimated that 40%-45% of children living in developing countries are too short for their age. This growth retardation is a sign of chronic malnutrition from multiple nutritional deficiencies, particularly energy deficiency, but also from repeated infections. It has been said that the number of children with retarded growth reflects the overall economic conditions of a country.

Just like acute malnutrition, growth retardation hampers the intellectual development of a child. It is obvious that children who are hungry at school pay less attention and do not learn as well. These children, in poor health and suffering from chronic malnutrition, particularly when accompanied by anaemia, during the crucial period of the first years of schooling, often have reduced learning capacity. This emphasises the importance of detecting these children time and to provide them with appropriate food supplements i.e. in the schools. As indicated in Chapter 3, a daily intake of several grams of *spirulina* during the meal distributed by the school kitchen can spectacularly improve these children's nutritional status.

## 2.2 Nutritional anaemia

The WHO describes nutritional anaemia as a state in which the blood haemoglobin content - or the number of red corpuscles - is below normal. It is the result of the deficiency of one or more nutrients involved in the synthesis of haemoglobin, which are: iron, most frequently; folic acid, less often; and, rarely, Vitamin B12. Iron deficiency should be particularly stressed because of its frequency and its impact on the physical and mental development of the child. Iron deficiency, however, is not restricted to the child: it also affects the pregnant woman and has an impact on the pregnancy's development and on adults, whose work capacity reduces. Iron deficiency is the biggest health problem in the world, since it affects more than 2 billion individuals. In some population groups in Africa, more than 50% of people are deficient in iron.

### 2.2.1 Causes of nutritional anaemia

The cause of nutritional anaemia can be (1) an insufficient nutrient intake, (2) poor nutrient assimilation, or (3) an increased need for one or more nutrients necessary for the manufacture of haemoglobin.

- (1) Insufficient iron intake: the infant and young child has particularly high iron requirements related to the rapid expansion of tissues and blood volume. If their diet is iron poor - which is generally the case for milk products - they run the risk of a deficiency. New-borns with low birth weight (premature babies, twins, etc.), who have low iron reserves and even higher requirements, are particularly exposed.

Most diets contain sufficient folic acid and Vitamin B12. However, prolonged cooking of foods, particularly vegetables, can lead to folic acid deficiency and the complete exclusion of animal products from the diet can exceptionally lead to Vitamin B12 deficiency.

- (2) Poor iron assimilation: the type of food and the level of the body's iron reserves determine the rate of assimilation of iron. It increases when the diet includes animal products or Vitamin C. In diets based exclusively on vegetables, iron is poorly assimilated. Other factors present in the diet such as tannins in tea hinder its assimilation. This is probably the reason why severe anaemias are so often found in some regions of the world, as in Asia.
- (3) Increased iron requirements: an increase in iron requirements can be physiological, as is the case during growth or pregnancy, or pathological, e.g. during repeated bouts of malaria, schistosomiasis or certain intestinal parasitic diseases such as ankylostomiasis.

These different causes - insufficient intake, poor assimilation and increased requirements due to parasitic disease - can coexist in the same child, which explains the scale and severity of anaemia in some children, particularly those from the most underprivileged socio-economic environments.

### 2.2.2 Consequences of anaemia

When anaemia is severe, the symptoms in children are pallor, a lack of appetite, apathy, and high susceptibility to infection and often growth retardation. Blood tests then show haemoglobin rates far below the normal level. These anaemic children also frequently suffer from protein-calorie deficiency. When nutritional anaemia adds its effects to those of malnutrition, it becomes a cause of excess mortality.

It should be noted that in most children in the Third World the clinical signs of anaemia are poorly defined. The haemoglobin level stays at the lower limit of the normal and only thorough blood tests enable the underlying iron deficiency to be detected. Although not anaemic, these children are no less susceptible to infection and also tend to be backward in school because of their inability to concentrate and to pay full attention in class.

### 2.2.3 Management of nutritional anaemias

Nutritional anaemias can be overcome (1) by an intense iron treatment or (2) by prevention altogether.

- (1) The *treatment* consists of administering iron compounds orally. The iron contained in syrups, drops or pills intended to treat childhood anaemia should of course be readily assimilable, while at the same time being inexpensive and well tolerated. Generally the treatment consists of doses of 3mg of iron sulfate per kg and per day, in 3-week courses repeated several times during the year.
- (2) The *prevention*: the most obvious solution is to increase the quantities of iron and folic acid in the diet and reduce losses of iron from the organism. This presupposes changes in dietary habits and the introduction of programmes for the control of parasitic diseases.

The increased consumption of substances that enhance iron assimilation, such as foods of animal origin, would certainly be useful but for cultural or economic reasons is not achievable everywhere. This raises the value of *spirulina*, whose content of iron (580-1800mg/kg), folic acid (0.5mg/kg) and Vitamin B12 (1.5-2mg/kg) makes it an excellent food supplement for the prevention of nutritional anaemia. It should be noted that the bioavailability of iron in *spirulina* is equal to that of iron sulfate.

Another measure is to enrich foods with iron. The choice of the food vehicle and the iron compound is of the greatest importance. The food vehicle needs to reach the population at risk of deficiency, but the enrichment process should not alter colour or flavour. Various foods are currently enriched, e.g. wheat flour, milk powder, sugar and fish sauce. The iron compound should be readily assimilated, stable and inexpensive. It is still difficult to meet all these criteria and only a few enrichment programmes have yielded good results.

For all these reasons, the administration of *spirulina* is a preferred method for the control of nutritional anaemias in the young child, but also in pregnant women and adults.

## 2.3 Vitamin A deficiency

Vitamin A deficiency is common above all in south-east Asia - Indonesia, Bangladesh, Viet Nam - and in the Middle East and Haiti. This deficiency is serious because of the eye lesions it causes, which can lead to blindness at a young age. It is estimated that nearly 500 000 children become blind every year. This deficiency is known as xerophthalmia, which means: "dry eye", because the dryness of the eye is the easiest symptom to recognise. Xerophthalmia is almost always associated with protein-calorie malnutrition and causes high mortality.

### 2.3.1 The dietary sources and roles of Vitamin A in the organism

Vitamin A, or retinol, is present in foods of animal origin, especially liver - cod liver oil is very rich in it - and milk, including human milk. Its name of retinol refers to its function in the retina: it makes sight possible in dim light. Above all, however, it protects the conjunctiva, which becomes dry in the event of deficiency (xerophthalmia), and the cornea, which in deficiencies becomes opaque and then ulcerated (keratomalacia). The role of Vitamin A is thus to protect the epithelium; it also promotes the child's growth and protects it against infections.

This Vitamin is also found in the form of precursors called proVitamin A in plants: these are the beta-carotene's found in green leaves, certain fruits - mango, papaya - and palm oil. In *spirulina* beta-carotene represents 0.15%-0.20% of its dry weight. The child's organism is capable of transforming these beta-carotenes into retinol, which is then stored in the liver, but this process requires a large enough intake of proteins. This explains why symptoms of deficiency appear only when the deficiency extends over several months. Once the deficiency is established, the deterioration of the eye progresses very fast and becomes irreversible if not treated from the first appearance of the symptoms.

### 2.3.2 Causes of Vitamin A deficiency

This deficiency appears under certain conditions related (1) to the diet, (2) the child's age, (3) associated infections and (4) weaning from breast milk.

- (1) Vitamin A deficiency is caused by an inadequate intake of transformed Vitamin A (retinol) or proVitamins (beta-carotene). It is found particularly in Asia, as rice does not contain beta-carotene, and among the most underprivileged sections of the population which have no access to very costly animal products and consume little fruit or green-leaf vegetables.
- (2) Children under the age of 4 years are the most threatened, especially if they suffer from protein-energy malnutrition. Infants are often affected in the months that follow weaning. The severe forms of xerophthalmia are rare in school-age children and adults, although minor signs of deficiency (Bitot's spots, night blindness, etc.) can occur in these groups.
- (3) Infections and xerophthalmia occur together. In a mildly malnourished child an infectious episode such as a bout of diarrhoea or a respiratory tract infection often leads to an overt state of malnutrition and simultaneously provokes xerophthalmia. Measles also has a predisposing role. Moreover, when diarrhoeas

are prolonged or repeated they reduce absorption of Vitamin A or proVitamin A.

- (4) Maternal breast-feeding protects against xerophthalmia unless the mother herself has very low Vitamin A reserves. It should be stressed that skimmed milk contains only very small quantities of Vitamin A and that a child fed exclusively on skimmed milk is at risk of developing a deficiency. That is why skimmed milk should be systematically enriched with the Vitamin.

### 2.3.3 Detection of xerophthalmia

Various signs, some more serious than others, indicate Vitamin A deficiency.

- (1) Loss of night vision: this problem is easily noticed by adults who experience difficulties in finding their bearings and direction in the evening at dusk. In contrast, this initial sign is rarely recognised in the young child. After the administration of Vitamin A, this problem disappears after 2 or 3 days of treatment.
- (2) Dryness of the conjunctiva: this dryness of the eye or conjunctival sclerosis is one of the first objective signs in the young child. The conjunctiva then gradually loses its brilliance and transparency, becoming dull and lifeless. When Vitamin A is administered the lesions vanish very fast.
- (3) Bitot's spots: at a later stage, the surface of the eyeball shows whitish streaks or superficial spots, called Bitot's spots. They sometimes affect both eyes more or less symmetrically, but not constantly. This condition also regresses rapidly after administration of Vitamin A.
- (4) Corneal xerosis: if no treatment is given, the epithelium of the cornea is affected in turn. It too loses its brilliance, becoming dull and irregular. Opaque areas then appear on the cornea, which offers little resistance to infections. The progression from this stage, which is still reversible with treatment, to irreversible ulceration can be extremely rapid.
- (5) Corneal ulcer: when the cornea is ulcerated it can rupture. If an intervention is made at this stage, the lesions will scar over, leaving scars on the cornea that will alter the sight.
- (6) Keratomalacia: in other cases, all the layers of the cornea soften (keratomalacia), so that the crystalline fluid is expelled and the eyeball is destroyed. The eye is then lost. If the damage is bilateral, the child becomes blind.

It should be noted that the lesions caused by Vitamin A deficiency are not painful. That explains why all too often the child is taken belatedly to the health centre or hospital - all the more so since this deficiency occurs particularly among children from poor families, in regions with little development where medical services are often inadequate.

## 2.4 The public health importance of Vitamin A deficiency

It can be concluded from several recent surveys that every year 10 million children have xerophthalmia, 500'000 of them become blind, and 1-3 million children die from the consequences of Vitamin A deficiency. It is a dramatic event for a child when it goes blind. Yet it is also a problem for the country, for that child will remain on the fringes of any economic activity all its life and will be more or less at the charge of society.

“The cost of preventive action against xerophthalmia represents a tiny proportion of the amount that could be saved by reducing the burden a blind person represents for a country's economy.” (WHO)

## 2.5 Treatment of xerophthalmia

### 2.5.1. Emergency treatment

Whether the child is suffering from conjunctival dryness or incipient or advanced corneal xerosis, Vitamin A must be administered, at high doses. Treatment is urgent because sequels of the lesions must be prevented. One or two high-dose capsules (according to age) of retinol palmitate should be administered.

### 2.5.2. Preventive treatment

The best solution is to improve the Vitamin A status of the population by increasing the availability of Vitamin A - but also proteins and fats - in the diet and educating future mothers in the use of foods rich in Vitamin and proVitamin A. In many countries where xerophthalmia is common, vegetables, leafy greens and fruits are available, but they are not used enough in the diet of infants and young children. A big effort of nutritional education is therefore essential. To change dietary habits is a long-term task but, once done, has lasting effects. Such an effort lies behind the disappearance of xerophthalmia in China. The current method used in countries such as Bangladesh with a high prevalence of xerophthalmia is the systematic administration of Vitamin A capsules. However, the children of underprivileged families - those at greatest risk - are the forgotten ones in these distributions of capsules. To have a readily accessible and easily usable source of proVitamin A would be a real advance in the fight against this scourge.

*Spirulina*, which contains 700-1700mg of beta-carotene per kg, is a very valuable source of proVitamin A. A study among 5000 pre-school Indian children showed the effectiveness of a single daily dose of 1g of *spirulina*. After 5 months of administration of *spirulina* powder, the prevalence of Bitot's spots fell from 80% to 10%.

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## Chapter 3

### Utilization of *spirulina* in children

*Spirulina* can be used at any age (from infancy to pregnancy and adulthood), but its value is particularly evident in the young growing child: during weaning and during the pre-school period (from 1 to 6 years).

#### 3.1 Use of *spirulina* in weaning paps

It hardly needs recalling that up to the age of 4 (and often 6) months breast milk and nothing else meet the child’s nutritional requirements. It is usual to introduce a supplementary food between 4 and 6 months in the form of a pap, while of course continuing to breast-feed. Paps are made of a mixture of flour (flour from cereals such as rice or maize or manioc flour) and a food rich in proteins, with a little oil and sugar added.

Foods rich in protein such as powdered milk, fish, peanut butter or soya are out of reach of the poorest people in some countries. *Spirulina* can successfully replace these sources of protein, for it is itself rich in very digestible proteins of good nutritional quality. To give an example, in sub-Saharan Africa 100ml of a pap of excellent nutritional value can be prepared by using manioc flour and *spirulina* as a basis in the following proportions:

Manioc flour	30g
<i>Spirulina</i>	5g
Oil	4g
Water	100ml

This pap should be given to the child once or twice a day in addition to breast-feeding. If the mixture is too thick, a little water should be added while cooking.

The preparation of a weaning pap should be based on foods available locally. The best approach is to watch how the mother usually prepares the weaning food and then enrich it with a supplementary source of protein by adding *spirulina*. The food habitually eaten by the family (family meal) can also be used as the basis to make a fluid pap by adding water and enriching it with *spirulina* during the cooking.

Different studies carried out in Africa and Asia have shown that children very well tolerated the addition of 5% of *spirulina* to cereal flour. Most importantly it enabled them to get over the hurdle of the weaning period. In other words to reach the age of eating adult food in good health.

#### 3.2 Use in the older child

When the child begins to join in the adults’ food, i.e. towards the age of 18 months to 2 years, it is not entirely safe from developing deficiencies. Particularly if that food is low in animal and vegetable proteins (which is unfortunately the case in a large fraction of the population in developing countries). Thus it is of great value to offer the child a supplementary source of protein such as *spirulina*. It can be administered in the form of cakes distributed at schools or powder mixed in the sauces accompanying dishes or even salads from plants.

As has been demonstrated in India, the addition of even a small quantity of *spirulina* has effected a clear improvement in the general status, weight and biological indicators (levels of serum albumin, haemoglobin, ferritin, retinol) in moderately malnourished preschool children.

In conclusion, two imperatives for the correct use of *spirulina* as a source of proteins should be mentioned.

First, *spirulina* does not replace breast milk, so that it is essential for maternal breast-feeding to continue in young children, if possible up to the age of 1 year. Secondly, it is not (yet) recognised as “good” traditional food for the child in many populations, so that mothers and health staff in general must be convinced by a constant effort of education and communication.

### Chapter 3 References:

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