CHOICE OF FOODS AND INGREDIENTS FOR

MODERATELY MALNOURISHED CHILDREN

6 MONTHS TO 5 YEARS OLD

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<td>AAS</td>
<td>amino acid score</td>
</tr>
<tr>
<td>ALA</td>
<td>alpha-linolenic acid</td>
</tr>
<tr>
<td>ATP</td>
<td>adenosine triphosphate</td>
</tr>
<tr>
<td>BCAA</td>
<td>branched chain amino acids</td>
</tr>
<tr>
<td>CSB</td>
<td>corn soy blend</td>
</tr>
<tr>
<td>DMT1</td>
<td>divalent metal transporter</td>
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<tr>
<td>E%</td>
<td>energy percent</td>
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<tr>
<td>FBF</td>
<td>fortified blended foods</td>
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<tr>
<td>FE%</td>
<td>fat energy percent</td>
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<tr>
<td>FPC</td>
<td>fish protein concentrate</td>
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<tr>
<td>Igs</td>
<td>immunoglobulins</td>
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<tr>
<td>LA</td>
<td>linoleic acid</td>
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<tr>
<td>LAL</td>
<td>lysinoalanine</td>
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<tr>
<td>MM</td>
<td>moderately malnourished/moderate malnutrition</td>
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<tr>
<td>NNR</td>
<td>Nordic Nutrition Recommendations</td>
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<tr>
<td>OFSP</td>
<td>orange flesh sweet potatoes</td>
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<tr>
<td>PDCAAS</td>
<td>protein digestibility corrected amino acid score</td>
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<tr>
<td>PE%</td>
<td>protein energy percent</td>
</tr>
<tr>
<td>PHA</td>
<td>phytohaemagglutinin</td>
</tr>
<tr>
<td>PUFA</td>
<td>polyunsaturated fatty acids</td>
</tr>
<tr>
<td>RUTF</td>
<td>ready-to-use-therapeutic-foods</td>
</tr>
<tr>
<td>SCFA</td>
<td>short chain fatty acids</td>
</tr>
<tr>
<td>SMP</td>
<td>skimmed milk powder</td>
</tr>
<tr>
<td>TD</td>
<td>true digestibility</td>
</tr>
<tr>
<td>WFP</td>
<td>World Food Programme</td>
</tr>
<tr>
<td>WMP</td>
<td>whole milk powder</td>
</tr>
<tr>
<td>WPC</td>
<td>whey protein concentrate</td>
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<td>WSB</td>
<td>wheat soy blend</td>
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Abstract

There is consensus on how to treat severe malnutrition, but there is no agreement on the most cost-effective way to treat infants and young children with moderate malnutrition (MM) who consume cereal dominated diets. The aim of the review is to give an overview of nutritional qualities of relevant foods and ingredients in relation to the nutritional needs of children with MM and to identify research needs. The following general aspects are covered: energy density, macronutrient content and quality, minerals and vitamins, bioactive substances, anti-nutritional factors, and food processing. The nutritional value of the main food groups - cereals, legumes, pulses, roots, vegetables, fruits and animal foods - are discussed. The special beneficial qualities of animal-source foods, with high levels of minerals important for growth, high protein quality, no anti-nutrients and fibres are emphasised. In cereal dominated diets the plant foods should be processed to reduce the content of anti-nutrients and fibres. Provision of a high fat content to increase energy density is emphasised; however, the content of micronutrients should also be increased to maintain nutrient density. The source of fat should be selected to supply optimal amounts of PUFA, especially n-3 fatty acids. Among multiple research needs the following are highlighted: to identify the minimum quantity of animal foods needed to support acceptable child growth and development, to examine the nutritional gains of reducing contents of anti-nutrients and fibres in cereal and legume based diets, and to examine the role of fat quality, especially PUFA content and ratios, in MM children.
INTRODUCTION

Child malnutrition is a major global health problem, leading to morbidity and mortality, impaired intellectual development and working capacity, and increased risk of adult disease. This review will deal with the needs of children with moderate malnutrition (MM) between the ages of 6 months and 5 years. Infants below 6 months should (ideally) be exclusively breastfed, and if malnourished, will have special needs, which will not be covered here. Moderate malnutrition includes all children with moderate wasting defined as a weight-for-height between -3 and -2 z-scores of the median of the new WHO child growth standards and all those with moderate stunting defined by a height-for-age between -3 and -2 z-score. There are no specific recommendations on the optimal treatment of children with severe stunting, but it is assumed that children with severe stunting would benefit from a diet adapted for moderately stunted children, as pointed out in the proceedings from the meeting on treatment of moderate malnutrition [1]. Throughout this review we have therefore not distinguished between children with moderate and severe stunting.

A recent analysis by the Maternal and Child Malnutrition Study Group (MCUSG) of data from 388 national surveys from 139 countries from 2005 [2], has provided new estimates of the global prevalence of underweight, stunting, and wasting among children below 5 years, based on the new WHO Child Growth Standards. Of the 556 million children under 5 years in low-income countries, 20% (112 mio) were underweight, 32% (178 mio) were stunted, while 10% (55 mio) were wasted, including the 3.5% (19 mio) severely wasted. Thus, about 36 million children are suffering from moderate wasting. Underweight, stunting and wasting each contributes to child mortality and disease burden. Of the almost 10 million deaths annually among children below 5 years it was estimated that the attributable fraction of underweight, stunting and wasting were 19, 15 and 15%, respectively, whereas intra-uterine growth restriction/low birth weight accounted for only 3.3%. Altogether, these anthropometric indicators of malnutrition, using – 2 SD (Z) as cut-offs, accounted for 21.4% of child mortality and 21.1% of child disease burden [2]. Of the 14.6% of deaths attributable to wasting, only 4.4% were due to severe wasting, hence 10.2% of the deaths or about 1 million were due to moderate wasting.

The typical diet in populations with a high prevalence of malnutrition consists predominantly of a starch-rich staple, such as a cereal (maize, rice), tuber (cassava), with limited amounts of fruits, vegetables, legumes and pulses, and little or no animal source foods. Such a diet is bulky, has a low density of energy and nutrients, and a low bioavailability of minerals, and will result in impaired growth, development, and host defence to infections. In addition, if introduced too early or if contaminated will lead to frequent infections, which will further impair nutritional status and, hence, increase risk of infectious diseases. Young children are also likely to be more
sensitive to the effect of anti-nutrients, e.g. high levels of phytate, impairing absorption of several growth limiting minerals, like zinc. Infants and young children are especially vulnerable to malnutrition because they have a high growth velocity and also a high energy and nutrient need. Growth velocity up to the age of about 2 years is especially high and it is also during this period that the brain reaches almost 90% of the adult size. Global figures on nutritional status have also shown that malnutrition among children below 5 years develops mainly during the 6-18 months period [3]. This period, which is the complementary feeding period, will therefore of special importance and will be given special attention in this review. Breastmilk is not included among the foods discussed in this review, as the importance of breastfeeding, especially for malnourished infants and young children, has been emphasised in many other reviews. In the treatment of moderate malnutrition it is very important that breastfeeding is continued whenever possible and that the dietary treatment given is not replacing breastmilk.

As pointed out in the review by Golden on the nutritional requirements of moderately malnourished children [4], the nutritional needs of a wasted and a stunted child differ. Especially, the time needed to reverse the condition will differ considerably between wasting and stunting. It will often be possible to reverse moderate wasting within 2-4 weeks, while reversing moderate stunting may take months or years, if at all possible. Reversing stunting is easier the earlier treatment is started, and especially the first two years seem to be a “window of opportunity”. Thus, the requirements of stunted children may be different in different age groups. The main difference between the requirements of wasted and stunted children will be that wasted children have a higher energy requirement and therefore also will benefit from a higher energy density and a higher fat content of the diet, provided the need for other nutrients is covered. If stunted children, with no wasting, are given a diet with high energy density and high fat content over longer periods, there is a risk that they will develop obesity. However, in populations with a high rate of malnutrition it is likely that those in the age group from 6-24 months would benefit from a relatively high energy density, even if they have not yet developed moderate wasting or are “only” moderately stunted. Thus a diet with a high energy density could have an important role in preventing moderate malnutrition in such populations. When the need for other nutrients is expressed in relation to energy content, it is likely that the requirements will not differ much between children with moderate wasting and stunting [4;5]. Other factors might also influence the requirements of a moderately malnourished child. The needs are likely to be different if the child is malnourished because of gastrointestinal problems with impaired absorption of nutrients, or malnourished mainly due to recurrent infectious diseases, compared to a child with malnutrition mainly due to in insufficient diet.
The aim of this review is to identify *foods and ingredients* appropriate to treat moderately malnourished children. These foods should be used to create a *diet*, which can fulfil the requirements of moderately malnourished children. Some foods and ingredients of limited availability may only be appropriate as part of homebased diets in specific settings, whereas others could be used in food supplements distributed by international organisations, NGO’s and governments. In Table 1 the desirable characteristics of such a diet are outlined and these characteristics will be discussed in detail in this review. Individual foods and ingredients may only fulfil some of these characteristics. For instance, green leafy vegetables may provide a high content of micronutrients and be a valuable food, although they have low fat and low energy content.
Table 1 Important characteristics of diets appropriate for children with moderate malnutrition

- High content of micronutrients, especially growth (type II) nutrients
- High energy density
- Adequate protein content
- High protein quality and availability
- Adequate fat content
- Appropriate fat quality, especially n-3/n-6 PUFA content
- Content of some animal source foods
- Low content of anti-nutrients
- Low risk of contamination
- Acceptable taste and texture
- Culturally acceptable
- Easy to prepare
- Affordable and available
NUTRITIONAL QUALITIES OF FOODS AND INGREDIENTS

Energy Density

The energy density is one of the most important qualities of foods for wasted children. If the energy density is too low the food becomes too bulky, and the child will not be able to eat adequate amounts. Infants and young children have a limited gastric capacity and an energy requirement per unit body weight about three times as high as adults. If a diet has a very low energy density even non-malnourished children may not be able to eat adequate amounts because the bulkiness of the diet. The energy density is most important for children with wasting, as they have an increased energy need for catch-up growth.

The most important factor influencing energy density is the fat content, as the energy density of fat (9 kcal/g) using the Atwater factors is more than double that of protein and carbohydrate (4 kcal/g). Another important factor is the water content. A biscuit will typically have an energy density of 4 kcal/g, while it is much lower in gruels and porridges given to infants. It will typically have a density between 0.6 and 0.8 kcal/g, but down to 0.25 kcal/g if it is only based on cereal and water [6]. The energy density of gruel and porridge is influenced by the type of flour, the fibre content, the flour processing, how the porridge is cooked and which ingredients are added. The energy density of a meal is calculated as the crude energy content of the ingredients, not taking into account that some of the energy is not available, like for example that of fibres. It is likely that this unavailable fraction is higher in malnourished infants and young children than in healthy adults.

Brown et al has described in detail how different levels of energy density can influence energy intake and how this is also affected by the number of meals given [7]. The effect of meal frequency and energy density on energy intake was examined in 6-18 months old Peruvian children recovering from malnutrition [8]. The energy densities of the diets were 0.4, 0.7, 1.0 and 1.5 kcal/g. When controlling for the number of meals (from 3-5 per day), the energy intake increased with higher energy densities. However, there were some adjustments, as the children were eating smaller amounts. Although the amount eaten was less with the higher energy densities, the children did not compensate fully. Interestingly, when the energy density increased from 1.0 kcal/g, which is usually considered an adequate energy density, to 1.5 kcal/g, the energy intake per kg body weight increased by approximately 20-25%.

In a review of complementary feeding, nine studies comparing energy intake in malnourished children receiving diets with different energy densities were identified [7]. In six of the studies energy intake was considerably higher when the children were given an energy dense diet. In most
of the studies the levels of the energy density in low energy density diet were about 0.5 kcal/g or lower. However, one of the studies in 5-18 month old malnourished children from Bangladesh compared a diet of 0.92 kcal/g with that of a diet with 1.47 kcal/g and also found an increase, about 50%, in the energy intake in the group on the energy dense diet [9]. Thus, increasing energy densities to above 1.0 kcal/g also resulted in increased energy intake among malnourished children. Several studies have shown that Ready-to-Use-Therapeutic-Foods (RUTFs) are very effective in treating severely wasted children [10-12]. A key characteristic of RUTFs is the very high energy density, about 5 kcal/g. However, in populations with a high rate of malnutrition it is likely that those in the age group from 6-24 months would benefit from a relatively high energy density, even if they have not yet developed moderate wasting or stunting. Thus an energy dense diet could have an important role in preventing moderate malnutrition in such populations. In addition to the high energy density, other characteristics, such as the supply of milk protein, the fact that they are nutritionally complete for micronutrients and the fact that they can be eaten without preparation and that most children like it, are likely to contribute to the effectiveness of RUTFs.

In 6-18 month old children not being breastfed, the minimum energy density of the diet, assuming 3 daily meals and a functional gastric capacity of 30g/kg body weight, has been calculated to between 1.00 and 1.08 kcal/g [13]. If the child received 5 meals per day the minimum values were from 0.60 to 0.65 kcal/g. In the 1980s Cameron and Hofvander suggested that the energy density of diets given to non-malnourished children in low-income countries should be considerably higher, between 1.5 and 2.0 kcal/g, to provide enough energy [14]. However, these estimates were based on the energy requirements from 1985 [15], which at that time were estimated about 20% higher than current estimates [16].

Diets with a considerably higher energy density than 1 kcal/g and even 2 kcal/g may be beneficial in treating moderately wasted children. These children have an increased energy need for catch-up, and some will have a poor appetite with an inability to eat large amounts. One of the reasons that RUTFs have been so successful in the treatment of severe wasting is likely to be the high energy density of about 5 kcal/g. However, there is a need for intervention studies examining the potential effects of a high energy diet given to children with MM. A potential adverse effect of a diet with a high energy density in breastfed infants could be a reduction in breastmilk intake as shown in two studies [17;18]. However, other studies could not find such an effect [19;20].

A high energy density can be achieved by reducing the water content of the food, and by adding oils or sugar. It is usually considered that it is difficult to produce gruels and porridges with an energy density above 1.5-2.0 kcal/g. Reducing the water content will result in foods which are not easy for infants and young children to eat because of inappropriate texture and viscosity and if sugar and other water soluble ingredients are added in high amounts, the osmolarity will easily
become too high. Preferably the osmolarity should not be much above 300 mOsm/kg [4]. Adding more oil to the diet will not have these negative effects but the acceptability of adding considerably higher amounts of oil to the foods given to MM children should be examined further (see section on fat content below). However, when high amounts of oils are added to the diet, it is, as with adding other ingredients with “empty calories” like sugar, very important that the nutrient density in the remaining diet is adequate. In populations with a high rate of malnutrition it is likely that those in the age group from 6-24 months would benefit from a relative high energy density, even if they have not yet developed moderate wasting or moderate stunting. Thus, an energy dense diet could also have an important role in preventing moderate malnutrition in such populations.

Conclusions and recommendations on energy density

- Children with stunting have smaller energy requirements than children with moderate wasting and therefore do not have the same need for foods with a high energy density. It will probably not be much higher than for children without malnutrition.
- Energy densities between 1 and 1.5 kcal/g are recommended for infants and young children with stunting.
- Giving a diet with a high energy density for a long period to stunted children, could potentially lead to obesity.
- For children with moderate wasting foods with energy densities between 1.5 and 2.0 kcal/g should be preferred.
- High energy densities can be obtained by adding fats or oils to the food, which will not increase the osmolarity.

Research recommendations

- Research is needed to further define the optimal energy density among both stunted and moderately wasted children
- It should be investigated if energy densities higher than 2.0 kcal/g given to children with moderate wasting, have advantages and can increase gain in lean body mass

Water Content

Water content of foods differs considerably from a very high content in liquid foods to dry foods with a very low content, like biscuits. Semi-liquid foods or foods fed with a spoon, like porridges and mashes, are important in the diet of infants and young children, and here the water content is an important determinant of important characteristics like energy density and viscosity. High water
content in a food reduces the energy density and whereby it becomes more bulky, and if the content is too high negatively influence energy intake. On the other hand low water content will increase the viscosity of the food, and may make it difficult for young children to eat.

Foods with very low water content, like RUTFs or biscuits, have a long shelf life as the low water content impair microbial growth if contaminated. The minimum water requirement (the water content not bound to food molecules, expressed as the water activity level) for growth of microorganisms has been determined [21]. For bacteria it is typically 0.85, and for yeast and moulds down to 0.61. Fresh meat has a water activity level of 0.99, bread 0.95, biscuits 0.3 and milk powder 0.2. RUTFs have a water activity level about 0.4 and a shelf life up to two years.

If foods with low water content are given, like biscuits, there is a need to cover the water requirements in another way, through drinks. If the child drinks unboiled water, the risk of infections from contaminated water is increased, when compared to a situation where the child will receive water in foods which have been boiled or heated, provided the food is given just after preparation and is not contaminated before consumption. As pointed out in the review by Golden it is especially important that the water requirement is covered in malnourished children, as they have reduced ability to concentrate urine [4].

**Macronutrients**

**Protein**

Dietary protein content and quality is of major importance in the treatment of malnourished children. If the content, quality or availability is too low it will limit growth and thereby recovery. If the intake is above the requirement the surplus protein will be metabolised into energy which is not an energy efficient process. A surplus will also produce urea which adds to the renal solute load, which is a problem in malnourished children [4]. Furthermore, it might have a negative impact on appetite [22] which is especially harmful in the treatment of malnourished children. In severe malnutrition a high protein intake might compromise liver function [4], but to what degree this is the case for moderate malnutrition is not known. Finally, protein, especially if it comes from animal sources, is typically an expensive ingredient in a diet, which is another reason for not supplying a surplus of protein.

In deciding the optimal protein content of a diet for moderately malnourished children both the amount and the quality of protein should be taken into account. In the review by Golden [4] it is suggested that the protein requirement of children with MM should be at least 24 g protein
per 1000 kcal (equivalent to about 9.6 protein energy percent (PE%)) and preferably 26 g/1000 kcal (10.4 PE%) and that the Protein Digestibility Corrected Aminoacid Score (PDCAAS) should be at least 70%. These amounts take into account both the extra needs of moderately malnourished children for growth and the extra allowances needed during infectious diseases. This is considerably higher than in the recent WHO/FAO report on protein requirements [5] which recommended a minimum of 6.9 PE% assuming a catch up growth of 5 g/kg per day and 8.9 PE% if 10 g/kg per day is assumed. In a review on composition of fortified blended foods we suggested to aim for a PE% of about 12, taking into account that the food supplement would not cover the whole diet [23]. As suggested in the conclusions from this meeting it is recommended that the PE% in diets to children with MM should not be above 15 [1].

**Protein quality**

High protein quality is defined as protein that supports maximal growth. The various protein quality indexes include one or more factors related to the amino acid profile, digestibility and the presence of inhibiting or enhancing components in the food ingested.

Previously, *protein efficiency ratio (PER)* was the most widely used index for evaluating protein quality. It is defined as body weight gain divided by the amount of test protein consumed by a young growing rat. An important disadvantage of PER is the differences in growth patterns between rats and humans and the different amino acid requirements [24].

Protein digestibility corrected amino acid score (PDCAAS) is a more recent method to evaluate protein quality and has been introduced due to the weakness of other indexes such as PER. PDCAAS has been adopted by the FAO/WHO as the method of choice for evaluating protein quality in human nutrition [5]. PDCAAS represents the amino acids available after protein digestion. That is, the content of the first limiting essential amino acid in a test protein divided by the content of the same amino acid in a reference pattern of essential amino acids [25]. The index also includes the digestibility of the protein defined as the true digestibility of the test protein measured in a rat assay [24]:

\[
PDCAAS = AAS \times TD,
\]

where AAS is the amino acid score and TD is the true digestibility.

The highest PDCAAS value that any protein can achieve is per definition 1.0 or 100%, which means that 100% or more of the requirement of essential amino acids is achieved. A score above 100% should by definition be truncated to 100%, because any amino acid in excess of what is required for building and repairing tissues are catabolised. However, when calculating PDCAAS values of diets or foods with several ingredients the exact PDCAAS value of these ingredients is
important, also when above 100%. Truncation limits the information provided about the potency of a specific protein source to counteract and balance inferior proteins in mixed diets [25]. Therefore, PDCAAS values above 100% are used in this review without truncating.

There are several limitations that must be considered when using PDCAAS: the validity of using the protein requirement of children in a reference amino acid pattern; and the validity of using true digestibility and the truncation of values above 100%. The reference scoring pattern is based on the amino acid requirements of children older than one year [26]. The basic data were obtained from children who were recovering from malnutrition, which can question the relevance of these amino acid requirements for healthy children. In this review this should be seen as an advantage as the focus is on malnourished children. The reference pattern does not, however, include amino acids that may be important under specific physiological and pathological conditions, such as in children and adults suffering from HIV/AIDS [25]. Another limitation is that the list of the aminoacid requirements used to identify the limiting aminoacid only has one value for total sulphur aminoacids, a group which also include methionine, which is one of the limiting aminoacids in soy [25]. PDCAAS is based on protein input and output and may overestimate the protein quality, as it does not take into consideration amino acids that are left unabsorbed in the ileum and are used by bacteria in the colon instead. Similarly, amino acids that are bound to antinutritional factors and thereby unavailable for absorption are assumed to be digested when calculating the PDCAAS value [26]. Different PDCAAS values can be obtained for the same food item because of varying values of amino acids in various food tables. Thus, PDCAAS values for the same food might vary, as seen in Table 2, in which examples of PDCAAS values of different foods from the literature are given together with values we have calculated.
Table 2 PDCAAS values of different foods

<table>
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<tr>
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<th>PDCAAS (%) From literature</th>
<th>PDCAAS (%) a) Our calculations</th>
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<tr>
<td><strong>Animal Source Foods</strong></td>
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<td></td>
</tr>
<tr>
<td>Beef</td>
<td>92 b)</td>
<td>94</td>
</tr>
<tr>
<td>Egg</td>
<td>118 b)</td>
<td></td>
</tr>
<tr>
<td>Cow’s milk</td>
<td>121 b)</td>
<td>112</td>
</tr>
<tr>
<td>Whey protein concentrate</td>
<td>114-161 c, d)</td>
<td></td>
</tr>
<tr>
<td>Skim milk powder</td>
<td>124 c)</td>
<td></td>
</tr>
<tr>
<td><strong>Vegetable Source Foods</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oat</td>
<td>45-51 a)</td>
<td>60</td>
</tr>
<tr>
<td>Rapeseed meal</td>
<td>46 b)</td>
<td></td>
</tr>
<tr>
<td>Maize</td>
<td>52 a)</td>
<td>35</td>
</tr>
<tr>
<td>Wheat</td>
<td>54 a), 42 b)</td>
<td>37</td>
</tr>
<tr>
<td>Cassava</td>
<td>57 b)</td>
<td>44</td>
</tr>
<tr>
<td>Rice</td>
<td>65 b)</td>
<td>54</td>
</tr>
<tr>
<td>Black bean</td>
<td>72 b)</td>
<td>45</td>
</tr>
<tr>
<td>Yam</td>
<td>73 b)</td>
<td>55</td>
</tr>
<tr>
<td>Potato</td>
<td>82 b)</td>
<td>71</td>
</tr>
<tr>
<td>Soy</td>
<td>90 b), 91 b)</td>
<td>93</td>
</tr>
</tbody>
</table>

a) PDCAAS values calculated on the basis of data from USDA Nutrient database [27] and the National Danish Nutrient database [28] with reference to 2- to 5- y-old children recovering from malnutrition [25].

b) Source: [25]
c) Source: [24]
d) Source: [23]
e) Source: [29]
f) Source: [30]
g) Source: [26]
h) Source: [31]
Calculating the PDCAAS value for a food with two or more ingredients is complicated. It is not enough to know the PDCAAS value for each ingredient, if the limiting amino acid is not the same. If that is the case it is necessary to know the amino acid composition of each of the ingredients, to identify the limiting amino acid in the combined food.

There is strong evidence that adding animal source foods to diets for moderately malnourished children will improve growth and recovery. This could be due to the higher micronutrient intake or the lower intake of antinutrients, as described in the section on animal food sources. However, it is likely that the improved protein quality also plays an important role. We have therefore calculated how different amounts of milk (skimmed milk powder) and meat (beef) added to different vegetable source foods influence PDCAAS values. In Table 3 we have calculated how PDCAAS is influenced by exchanging 10%, 25% or 50% of the weight of the vegetable source food by milk or meat. In Table 4 we have made the same exercise but based on the protein content of the vegetable source food being replaced by protein from animal source foods.

Where the amount of animal food added is based on protein weight (Table 4) there is not much difference between the effect of milk and meat on PDCAAS. For the vegetable source foods with the lowest PDCAAS, wheat, maize, black bean and cassava, it is only when 50% of the protein is exchanged with an animal food source that the increases are up to a level of 80% or above. If only 25% of the protein is exchanged, the PDCAAS values are around 60% or lower. When the calculations are based on the weight of foods (Table 3), milk has a more pronounced effect on the PDCAAS than meat, because meat only contain 20% protein, compared to 36% in dry skimmed milk powder. Adding 25% milk powder brings PDCAAS values to a reasonable level, above 70 %, while the level, when adding meat, is only 60 % or slightly above, for wheat, maize or black bean.

If the aim is to increase PDCAAS of a combined vegetable and animal meal or diet to a level of 70-80 %, as suggested in the review by Golden [4], then adding about 33-40 % of the protein content as animal food to vegetable foods with the lowest PDCAAS values, would be sufficient. To make a significant impact on growth a prudent recommendation would be that at least 1/3 of the protein intake should come from animal products if the staple food has a low PDCAAS.

The calculations made here, combining only two foods are simple, compared to calculations for the total diet which typically will contain several other ingredients. These other ingredients could have a lower PDCAAS value, reducing the PDCAAS of the whole diet. But they could also have an amino acid pattern, which would complement the pattern of the remaining foods, resulting in a higher PDCAAS of the total diet.
Conclusions and recommendations on protein

- Protein intake and quality are important determinants of growth in the treatment of moderately malnourished children
- A surplus of protein in the diet may reduce appetite, and is an ineffective and costly source of energy
- A high protein quality, i.e. PDCAAS \( \geq 70-80\% \), should be aimed for
- Children receiving a diet with low PDCAAS would benefit from addition of animal source foods to the diet. It is suggested that about 1/3 of the protein intake should come from animal source foods to make a significant impact on growth
Table 3 PDCAAS values (%) with limiting amino acid in brackets if various proportions of the weight of a cereal, legume or root are exchanged with animal source foods.

<table>
<thead>
<tr>
<th>Food Item</th>
<th>0%</th>
<th>10%</th>
<th>25%</th>
<th>50%</th>
<th>10%</th>
<th>25%</th>
<th>50%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>37 (Lys)</td>
<td>55 (Lys)</td>
<td>75 (Lys)</td>
<td>98 (Lys)</td>
<td>49 (Lys)</td>
<td>66 (Lys)</td>
<td>92 (Lys)</td>
</tr>
<tr>
<td>Rice</td>
<td>54 (Lys)</td>
<td>75 (Lys)</td>
<td>93 (Lys)</td>
<td>110 (Lys)</td>
<td>70 (Lys)</td>
<td>88 (Lys)</td>
<td>98 (Lys)</td>
</tr>
<tr>
<td>Maize</td>
<td>35 (Lys)</td>
<td>56 (Lys)</td>
<td>78 (Trp)</td>
<td>95 (Trp)</td>
<td>50 (Lys)</td>
<td>62 (Trp)</td>
<td>76 (Trp)</td>
</tr>
<tr>
<td>Oat</td>
<td>60 (Lys)</td>
<td>73 (Lys)</td>
<td>88 (Lys)</td>
<td>105 (Lys)</td>
<td>69 (Lys)</td>
<td>82 (Lys)</td>
<td>96 (Trp)</td>
</tr>
<tr>
<td>Soy</td>
<td>93 (Lys)</td>
<td>96 (Lys)</td>
<td>99 (Lys)</td>
<td>106 (Lys/Trp)</td>
<td>95 (Lys)</td>
<td>98 (Lys)</td>
<td>100 (Trp)</td>
</tr>
<tr>
<td>Black bean</td>
<td>45 (SAA)</td>
<td>56 (SAA)</td>
<td>71 (SAA)</td>
<td>93 (SAA)</td>
<td>50 (SAA)</td>
<td>60 (SAA)</td>
<td>77 (SAA)</td>
</tr>
<tr>
<td>Potato</td>
<td>71 (SAA)</td>
<td>106 (SAA/Thr)</td>
<td>113 (Trp)</td>
<td>112 (Trp)</td>
<td>94 (SAA)</td>
<td>99 (Trp) a)</td>
<td>96 (Trp) a)</td>
</tr>
<tr>
<td>Cassava</td>
<td>44 (Lys)</td>
<td>85 (Lys)</td>
<td>103 (Thr)</td>
<td>111 (Trp)</td>
<td>74 (Thr)</td>
<td>92 (Thr)</td>
<td>95 (Trp)</td>
</tr>
<tr>
<td>Yam</td>
<td>55 (Lys)</td>
<td>96 (Trp)</td>
<td>105 (Trp)</td>
<td>110 (Trp)</td>
<td>78 (Trp)</td>
<td>87 (Trp)</td>
<td>91 (Trp)</td>
</tr>
</tbody>
</table>

a) Values decrease as trypsine is lower in beef than in soy

Table 4 PDCAAS values (%) with limiting amino acid in brackets if various proportions of the protein content of a cereal, legume or root are exchanged with animal protein.

<table>
<thead>
<tr>
<th>Food Item</th>
<th>0%</th>
<th>10%</th>
<th>25%</th>
<th>50%</th>
<th>10%</th>
<th>25%</th>
<th>50%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>37 (Lys)</td>
<td>45 (Lys)</td>
<td>57 (Lys)</td>
<td>79 (Lys)</td>
<td>46 (Lys)</td>
<td>60 (Lys)</td>
<td>84 (Lys)</td>
</tr>
<tr>
<td>Rice</td>
<td>54 (Lys)</td>
<td>61 (Lys)</td>
<td>71 (Lys)</td>
<td>88 (Lys)</td>
<td>62 (Lys)</td>
<td>73 (Lys)</td>
<td>93 (Lys)</td>
</tr>
<tr>
<td>Maize</td>
<td>35 (Lys)</td>
<td>42 (Lys)</td>
<td>54 (Lys)</td>
<td>75 (Lys + Trp)</td>
<td>43 (Lys)</td>
<td>55 (Trp)</td>
<td>67 (Trp)</td>
</tr>
<tr>
<td>Oat</td>
<td>60 (Lys)</td>
<td>65 (Lys)</td>
<td>74 (Lys)</td>
<td>90 (Lys)</td>
<td>66 (Lys)</td>
<td>77 (Lys)</td>
<td>95 (Lys)</td>
</tr>
<tr>
<td>Soy</td>
<td>93 (Lys)</td>
<td>96 (Lys)</td>
<td>101 (Lys)</td>
<td>107 (Trp)</td>
<td>97 (Lys)</td>
<td>100 (Trp) a)</td>
<td>98 (Trp) a)</td>
</tr>
<tr>
<td>Black bean</td>
<td>45 (SAA)</td>
<td>51 (SAA)</td>
<td>62 (SAA)</td>
<td>81 (SAA)</td>
<td>50 (SAA)</td>
<td>60 (SAA)</td>
<td>88 (SAA)</td>
</tr>
<tr>
<td>Potato</td>
<td>71 (SAA)</td>
<td>76 (SAA)</td>
<td>84 (SAA)</td>
<td>97 (SAA)</td>
<td>75 (SAA)</td>
<td>82 (SAA)</td>
<td>93 (SAA)</td>
</tr>
<tr>
<td>Cassava</td>
<td>44 (Lys)</td>
<td>51 (Lys)</td>
<td>62 (Lys)</td>
<td>81 (Lys)</td>
<td>52 (Lys)</td>
<td>64 (Lys + Thr)</td>
<td>80 (Thr)</td>
</tr>
<tr>
<td>Yam</td>
<td>55 (Lys)</td>
<td>61 (Lys)</td>
<td>70 (Trp)</td>
<td>84 (Trp)</td>
<td>61 (Trp)</td>
<td>66 (Trp)</td>
<td>75 (Trp)</td>
</tr>
</tbody>
</table>

a) Values decrease as trypsine is lower in beef than in soy
Fat

Fat content

Fat is an important source of energy for infants and young children. The fat content of human milk is high with about 50% of the energy coming from fat, underlining that fat requirements are high in early life. After introduction of complementary foods the fat content of the diet decreases, but there is at present no general agreement about the optimal level of fat in complementary foods and in diets for young children. Several recommendations from high-income countries have stated that there should be no restrictions in fat intake during the first years of life without giving a minimum level [32]. For complementary feeding of children who are not malnourished a level of 30-45% fat energy percent has been recommended, including the fat from breastmilk [33]. For foods used in emergencies a fat content of 30-40% has been recommended for complementary feeding [34]. In the WHO guidelines for non-breastfed infants and young children the amount of fat to be added to a diet, aiming at a fat energy percentage of 30 in the whole diet, has been calculated [13]. If the diet contains no animal source foods, it is recommended that 10-20 g of fat or oil should be added to the diet, while it is recommended that children eating animal source foods, including whole milk, should only be given an additional 5 g of fat or oil daily, equal to one tea spoon per day.

Two reviews have evaluated the evidence of a negative effect of a low fat energy percentage in the diet of children in low-income countries. Prentice and Paul [35] concluded that many children in low-income countries would benefit from an increased fat intake and they suggested a minimum level of 20-25 fat energy percent. They were cautious about recommending a much higher intake of fat, because of the potential risk of obesity and co-morbidities seen in many countries, but this is not likely to be a concern in the treatment of children with moderate malnutrition, where the period of treatment is limited. In an analysis of national data from 19 countries from Latin America, Uauy and co-workers [36] compared food balance sheets with prevalence of underweight, stunting and wasting in the countries. They found that a diet with less than 22% of energy from fat was likely to restrict growth and also that a low intake of animal fats was likely to have a negative effect on growth.

Fortified blended foods (FBFs), like CSB and UNIMIX, are given to children with moderate malnutrition. These blends have a low fat content, about 14-16 percent of the energy. They are meant to be distributed with separate provision of oil, but to what extent the oil is added to these FBFs when given to infants and young children is not known. In some programmes CSB is mixed with oil before it is handed out. The reason for not adding oil to the FBFs at production is that they would rapidly become rancid and have a shelf life of only some weeks. However, if oils with added oxidants are used the shelf life is longer.
Children with moderate malnutrition, especially those with moderate wasting, have an increased need for energy for catch-up growth and thus require a diet with a high energy density. A diet with high fat content is therefore likely to be beneficial for these children. It is interesting that foods used for treatment of children with severe malnutrition have a very high fat content. In F-100 about 50% of the energy comes from fat and in RUTFs it is between 50 and 60%.

Given the high energy needs of wasted children and the positive results obtained with foods with a high fat content in treatment of severe malnutrition it seems prudent to aim at a fat intake close to the upper limit of the range suggested in the review by Golden [4] which is 45 energy percent in treatment of moderately wasted children. In treatment of children with moderate stunting, who need treatment for longer periods, it is probably sufficient with a fat energy percent close to the lower limit which is 35 energy percent.

Conclusions and recommendations on fat content

- A low content of fat in the diet reduces the energy density and total energy intake.
- Diets for moderately malnourished children should aim at a fat energy percent between 35 and 45, and not go below a minimum level of 30 fat energy percentage.
- When increasing the fat content, there may be a need to also increase the content of other nutrients, to avoid a decline in the nutrient density.

Research recommendations

- It is plausible that children with moderate wasting would benefit from a diet with a fat content closer to the upper limit, while a fat content for children with moderate stunting will be sufficient. However, there is a need to perform studies to explore this further and to examine how different fat contents influence gain in lean body mass.

Fatty acid composition and content of essential fatty acids

Apart from supplying energy, dietary fat plays an important role in allowing adequate absorption of fat-soluble vitamins and an adequate supply of essential fatty acids. The differences between fat sources with respect to absorption of the fat soluble vitamins, vitamin A, D and E, appear to be small. About 5 g of fat has been found to be needed per meal to provide good bioavailability of vitamin A. The absorption seems to be improved somewhat by fat rich in oleic acid (C18:1), but other oils are probably almost as good [37]. Therefore, we assume the essential fatty acid issue to be the most relevant with respect to moderately malnourished children.

There are two types of essential fatty acids, the n-6 and the n-3 polyunsaturated fatty acids (PUFA), which in most diets are provided by vegetable oils in the form of linoleic acid (LA,
C18:2n-6) and α-linolenic acid (ALA, C18:3n-3) respectively. Essential fatty acids may also be supplied from meat and fish in their long-chained forms, arachidonic acid (AA, C20:4n-6), eicosapentaenoic acid (EPA, C20:5n-3) and docosahexaenoic acid (DHA, C22:6n-3).

According to the Nordic Nutrition Recommendations [38], the fat intake of young children (1-2 years) should have a quality that provides 5-10 E% as essential fatty acids including at least 1 E% of n-3 PUFA and have a ratio of n-6 to n-3 PUFA between 3 and 9. The need for essential fatty acids is expected to follow the need for energy and thus the requirements, expressed in weight of essential fatty acids, are expected to increase during a refeeding phase. The FAO/WHO recommendations from 1994 have a general statement, that the ratio of LA to ALA in the diet should be between 5 and 10 [39]. Furthermore, it is stated that during the complementary feeding period and at least until two years of age, a child's diet should provide similar levels of essential fatty acids as are found in breast-milk. According to the Codex Alimentarius Standard for Infant Formula [40] the ratio between LA and ALA should be between 5 and 15. These recommendations are based on the range of ratios found in breastmilk. However, the ratio in breastmilk tend to be high, up to 15, in populations where mothers have a very low intake of n-3 fatty acids, below the recommended intake [41]. Thus, it is likely that a range between 5 and 9 is more optimal. It makes most sense to use the ratio between n-6 and n-3 PUFA for fatty acids on the same metabolic level (LA and ALA or arachidonic acid vs. n-3 LCPUFA). However, most foods, except fish, have only a limited amount of long-chain PUFA (LCPUFA). For these foods the LA/ALA ratio is almost identical to the n-6/n-3 PUFA ratio.

Golden in his review suggests that the requirement for n-6 PUFA in moderately malnourished individuals is 4.5 g E% (equivalent to 5 g/1000 kcal) and the n-3 PUFA requirement is 0.5 E% (equivalent to 0.55 g/1000 kcal) [4]. Thus, these recommendations imply a n-6/n-3 PUFA-ratio of 9.

A conditional requirement for n-3 LCPUFA is presently established in premature infants, but more mature infants and older children may also benefit from an intake of preformed long-chain n-3 PUFA. The long-chain n-3 PUFA (EPA and DHA) are more efficiently used for tissue incorporation and specific body functions. In primates it has been shown that long-chain n-3 PUFA supplied to the diet of the pregnant or lactating mother are around ten times more efficiently incorporated into the foetal or infant brain [41]. Inclusion of a small amount of fish, with EPA and DHA, in the diet will make a great contribution relative to ALA with respect to fulfilment of the n-3 PUFA-requirements of all young children.

Infants and young children in low-income countries, who are born with a low birth weight and thus poor foetal stores, like premature infants, may be expected to be extra vulnerable and dependent on post-natal dietary supply of long-chain n-3 PUFA. Children in low-income
countries may have additional requirements due to environmental stress, such as infections. Therefore, we would suggest that more emphasis is given to secure an optimal intake of n-3 PUFA for children with MM.

*Fat composition in the diet*

The diets in most low-income countries consist mainly of basic stable foods - cereals, legumes and roots. Generally, the content of PUFA in these stable foods is low (except for peanut and soy, Table 15). The cereal staples and peanut have a relative high content of n-6 PUFA and only very small amounts of n-3 PUFA. It is thus plausible that the general trend is that the dietary intake of many malnourished children is closer to meeting the recommendations for n-6 PUFA than those for n-3 PUFA and these diets do not meet the recommended n-6/n-3 ratio. An exception could be populations where for example the intake of fish or soy oil is high. Only few studies have examined the dietary intake of children in low-income countries to an extent that allows adequate assessment of the intake of essential fatty acids. The most important fat sources in 24-36 month-old Gambian children have been found to be peanuts and peanut oil, cereals, and palm oil, which was found to supply 4.6 E% LA, sufficient according to recommendations, but only 0.13 E% ALA, giving a n-6/n-3 PUFA-ratio of almost 30 [35], much higher than 15, which is the upper limit seen in human milk in Western countries and thus in the current recommendations for infants [35;41]. However, in 1-5 year-old Chinese children with a high prevalence of stunting the daily intakes of essential fatty acids was found to be low (3.3 E%), but balanced with respect to the n-6/n-3 PUFA-ratio [42]. Other studies have looked at the dietary PUFA supply from breast-milk [43]. These studies show that the n-6/n-3 PUFA-ratio in human milk vary considerably between low-income countries, but in some low-income countries it has been found to greatly exceed 15 possibly due to a high and unbalanced intake of n-6 PUFA in the mothers’ diet. Thus, in a population with a low n-3 intake, breastfed infants will also have a low supply of n-3 PUFA, and consequently an increased need when they start complementary foods. Supplementing the diet of the lactating mother with foods with n-3 PUFA is therefore a way to improve the n-3 PUFA status of the young child.

*Symptoms and effects of insufficient fat intake*

The symptoms of severe n-6 PUFA-deficiency are scaly skin, impaired water balance, dehydration and poor growth [44], whereas the signs of n-3 PUFA-deficiency are less obvious as they manifest themselves in neurological symptoms, slow visual maturation, delayed motor skill development and impaired learning [41]. Furthermore, other studies suggest that essential fatty acid deficiency may result in increased infectious disease susceptibility, shortened erythrocyte survival, and some changes in structure and function of the heart, liver, gastrointestinal tract and other organs.
Long-chain n-3 PUFAs are specifically up-concentrated in the central nervous system. Several studies have shown that the intake of long-chain n-3 PUFA may affect the function of the central nervous system during early infancy [41], and that they may also affect cognitive development, attention, and behaviour [45;46]. An effect of DHA supplementation on cognitive function has been shown in preterm infants, most likely because they are born with small stores of long-chain PUFA (LCPUFA) [47]. As many infants in low-income countries are born with low birth weight to mothers who also have a low n-3 PUFA intake, they are likely to be deficient at birth and would probably benefit from a high n-3 PUFA intake, and preferably an intake of EPA and DHA from animal sources.

Only a few well performed studies have examined the PUFA-status in young children in low-income countries [48]. Some of these studies have shown high levels of the essential fatty acid deficiency indicators and most studies show low levels of DHA and n-6 PUFA in plasma or blood cell membranes, when compared to children from high income countries [48]. In a study comparing 18 months old children from Cambodia and Italy, the Cambodian children had lower levels of LA, but comparable ALA levels and higher levels of LCPUFA [49]. The higher levels could however be because they were still breastfed. Among the Cambodian children 27% were stunted and 5 % wasted. An intervention with micronutrients resulted in a significant increase in LA and ALA, but not of LCPUFA, suggesting that their PUFA metabolism was influenced by their poor micronutrient status.

Some of the symptoms of malnutrition may in part be explained by a lack of PUFA, e.g. the high infection rate [50] and skin changes [51]. Dry flaky skin is common in cases of moderate malnutrition and mothers of children treated with fat-based spreads often comment on the improvement of the skin during treatment [4]. Observational studies from China and Africa have suggested that a high n-6 fatty acid intake combined with a low n-3 fatty acid intake also has a negative effect on both weight gain and linear growth [42;52]. It is also plausible that the low n-3 PUFA intake could cause delayed cognitive development. Verbal learning and memory was improved in an intervention study in South Africa among school children receiving a bread spread with fish flour from a marine source [53].

Thus, essential fatty acid deficiency could be involved in several of the symptoms that are seen in malnourished children. However, there is a lack of intervention studies proving that insufficient PUFA intake causes some of the symptoms seen in children with moderate malnutrition, and that the children in fact would benefit from an extra supply.

Conclusions and recommendations on fat quality

- The intake of PUFA is likely to be low in children with moderate malnutrition
- The intake of n-3 PUFA seems to be especially low resulting in a high n-6/n-3 PUFA ratio
• Several of the manifestations in children with moderate malnutrition could be caused by PUFA deficiency, but evidence is lacking.
• It is recommended that diets for moderately malnourished children contain at least 4.5 energy percent of n-6 PUFA and 0.5 energy percent of n-3 PUFA
• The n-6/n-3 ratio in the diet should be below 15 and preferably between 5 and 9
• Foods with a high n-3 fatty acid content such as soybean and rapeseed oil, and fish should be promoted

Research recommendations
• Research is needed to define the optimal content of PUFA in diets to children with MM

Carbohydrate

Simple Sugars
The most important dietary mono- and disaccharides are glucose, fructose, lactose and sucrose (sugar). These sugars are good sources of energy and will typically increase the energy density of a diet. Sucrose can be added to foods given to children with MM. The advantages and disadvantages of using sugar are described in a separate section on sugar under "Foods and ingredients".

Lactose
Lactose comes mainly from milk and milk products. Lactose maldigestion and intolerance are prevalent in many populations in low-income countries, but symptoms are not common before the age of 3-5 years, and lactose maldigestion does not seem to be a major problem in the treatment of malnutrition [54,55]. Even if malnutrition has a negative effect on the intestinal lactase content the positive results of treating severely malnourished children with F-100, which contain about 21 g lactose per 100 g of dry F-100, suggest that the lactose content of foods given to children with moderate malnutrition is not likely to be a problem. Also RUTFs contain a considerable amount of lactose (about 12g/100g), which does not seem to cause problems when given to malnourished children. Studies of pigs have suggested that lactose may have a positive effect on growth, it enhances calcium absorption and is likely to have a beneficial luminal effect in the intestine [56]. Breast milk also has a high lactose content and it has been suggested that this has a prebiotic effect, i.e. stimulating the growth of a beneficial intestinal flora, as some of the lactose will enter the large intestine and act as indigestible fibre [57]. Lactose enhances the absorption of calcium, magnesium and perhaps phosphorus in infants [58]. However, there is no evidence that lactose improves calcium absorption in adults [59].
Starch
Starch is the most widespread polysaccharide in the human diet, and the main sources are staple foods such as cereal, roots and tubers. The staple food with the largest amount of starch is maize, but also wheat, rice and potato have high contents of starch. Starch is stored as amylose and amylopectin in granules in plant tubers and seeds [60]. Starch is a polysaccharide carbohydrate, consisting of $\alpha$-1-4 linked glucose monomers. Around 20-30% is amylose, a linear glucose polymer, while the remaining 70-80% is amylopectin, a branched polymer. The ratio of amylose to amylopectin varies between foods, e.g. some varieties of maize contain over 50% amylose whereas and other varieties have almost none [61].

$\alpha$-Amylase is a digestive enzyme which breaks down starch to maltose and dextrins. Dextrins are mixtures of linear glucose polymers. Amylose starch is less digestible than amylopectin. Maltodextrin is absorbed as rapidly as glucose, but does not have the same sweet taste [62].

A considerable fraction of starch, so called resistant starch, which is inaccessible to enzymatic digestion. Resistant starch may serves as substrate for the microflora in the colon where it is microbially degraded to short fatty acids, and therefore, physiologically, resistant starch may be considered a soluble dietary fibre [63]. Some short fatty acids may have anti-inflammatory properties [64;65].

Dietary Fibre
No universally accepted definition of dietary fibre exists. A useful and generally accepted definition is that dietary fibre consists of non-starch polysaccharides such as cellulose, hemicellulose, pectin, $\beta$-glucans, plant gums and mucilages. In some definitions of dietary fibre, resistant starch components like oligosaccharides and inulin and non-carbohydrate components like lignin, waxes, and chitins are also included. Dietary fibres are also called “non-digestible carbohydrates”, especially in relation to the physiological effects of these substances in infants and young children [57].

The most fibre-rich plant foods are unrefined cereals and legumes, including soy beans, beans, lentils and peas. All plant foods contain both insoluble and water-soluble dietary fibres, although in varying quantities. Insoluble fibres, e.g. celluloses, some hemicelluloses and lignin, are indigestible or only partially fermented in the large intestine. Insoluble fibres in the diet causes soft stools and shortens intestinal transit time, which may reduce the digestibility and availability of nutrients. Food processing like extrusion cooking can to some degree solubilise insoluble fibres, especially in wheat flour [66]. Soluble fibre, e.g. pectins, gums and mucilages, are found in all
plant foods, especially fruit and vegetables, but in varying amounts. Soluble fibres possess water-binding properties and are relatively rapidly fermented in the colon. Some soluble dietary fibres such as inuline can improve absorption of calcium [67-69].

Diets with a high content of soluble dietary fibres may lead to flatulence due to the relatively rapid fermentation in the large intestine [70]. Especially a group of oligosaccharides, α-galactosides, typically found in legumes, are digested in the colon by bacteria resulting in the production of short-chain fatty acids and gases causing flatulence. High intake of soluble dietary fibres has been shown to lead to negative effects on energy intake in the short term [71] as well as in longer term studies [72] in healthy subjects, and in malnourished children [73].

There are several studies and reviews dealing with the potential negative effect of dietary fibres on energy intake and growth in infants and children. Dietary fibres may reduce energy intake through a suppressing effect on appetite, and they may increase faecal losses of energy due to reduced absorption of fat and carbohydrate [57]. In a study from the Netherlands on infants and young children receiving a “macrobiotic” diet with a high content of dietary fibre (13 g/d) the weight gain and linear growth was reduced considerably compared to a control group [74]. The diet of these children was high in dietary fibre, low in fat content, contained no animal source foods and had an overall low energy density so the reason for this lower rate of weight gain in the children receiving the macrobiotic diet can not only be attributed to the high content of dietary fibre.

In an intervention study 7-17 week old infants were given weaning cereals with wheat/soy or with wheat/milk and with different fibre contents [75]. The intake of cereal was significantly lower (34 g/d) in a group with a high content of dietary fibres (8.0%) compared to the intake (42 g/d) in a group with a low intake of dietary fibres (1.8 g/d). There was no difference in apparent absorption of energy or nitrogen between the groups. There were more children withdrawn from the wheat/soy study than from the wheat/milk group because the infants refused the cereal or got sick. One third of the infants with the high fibre intake were reported to have gritty stools. The infants in the study were very young, and had no major problems from the high fibre diet, but they only had a limited intake of cereal with most energy coming from infant formula. The significant decrease in energy intake from the cereal and the higher withdrawal among those receiving the high fibre cereal is worrying in relation to vulnerable malnourished children.

The US reference intake of total dietary fibre for children 1-3 years is 19g/day, equivalent to 11g/1000kcal [76]. This is a very high intake and most likely too high for malnourished children, especially if they have gastrointestinal problems. A previous recommendation from the American Academy of Pediatrics was 0.5 g/kg body weight, which is much less, at one year of age only about ¼ of the IOM recommendation [77]. Another
recommendation suggested that from the age of 3 years the dietary fibre intake should be 5g plus one gram for each year of age [78].

In a population with a high risk of obesity and diabetes, a high intake of dietary fibres is recommended because of their effects on satiety, improved glucose tolerance and decreased serum cholesterol and triglycerides [57]. Another reason to recommend a diet with relatively high dietary fibre content to young children in the same societies is to accustom them to a high fibre diet. However, these arguments are not relevant for children with moderate malnutrition. The total intake of dietary fibre for children with MM should be as low as possible. Children under treatment for severe acute malnutrition with F-100 receive a diet with no dietary fibres. Furthermore, breastfed infants receive no fibres. Children with moderate malnutrition typically receive home-made diets based mainly on cereals and legumes as alternatives are costly. Such home-made foods are relatively high in insoluble dietary fibres.

If the dietary fibre content is very low it may result in constipation, but that is generally not an issue in children treated for malnutrition. It is recommended that insoluble fibres should be present in low amounts in the diet, because they increase bulk and reduce gastrointestinal transit time. Soluble dietary fibres are recommended in slightly larger proportion of the diet, because of their prebiotic properties, leading to an increased fermentation and support of the growth of a beneficial colonic microflora. It is probable that resistant starch and/or oligosaccharides – or other substrates resistant to digestion in the small intestine of the MM child – may have prebiotic properties in the MM child.

Until more evidence is available it is not possible to give recommendations for an upper level of intake of fibres that will not result in problems for children with MM. In dietary products used for children with MM the content of fibres and especially insoluble fibres should be kept as low as possible. This is especially important during the first two years of life and in children with gastrointestinal problems.

With a cereal based diet it is difficult to follow the lowest of the recommendation, the one from the American Academy of Pediatrics that the intake should be below 0.5 g/kg body weight per day. Assuming an energy intake of a child of 100 kcal/kg body weight and that 2/3 is covered by cereals and legumes, this will be equal to about 20 g of dry cereals and legumes per kg body weight. To fulfil the recommendation of not more than 0.5 g total fibre per kg body weight the content of total fibres in the cereals and legumes should be below 2.5 %. Thus, this recommendation can only be reached if the stable food is rice (Table 12) or if the amount of cereals and legumes is reduced.
Conclusions and recommendations on carbohydrates

- Lactose maldigestion and intolerance is generally not a problem in the treatment of children with MM
- Lactose may improve mineral absorption and have prebiotic effects
- Starch is an important and cheap source of energy for children with MM
- Dietary fibres increase bulk and satiety and reduce nutrient and energy digestibility, which may be harmful to children with malnutrition
- It is unknown to what degree fibres are available as energy in infants and children with MM, especially if they have gastrointestinal problems.
- In infants and children up to two years the fibre intake and especially the intake of insoluble fibres should be kept as low as possible until further evidence is available.
- There are inadequate data to determine an upper limit for intake of insoluble dietary fibres.
- The content of total dietary fibres and of insoluble fibres should be declared on foods produced to treat children with MM

Research recommendations

- There is a need to perform studies examining the effects of different levels of fibre intakes in children with MM, including measurements of the amount of energy in the stools
- There is a need for further studies to determine the physiological effects of resistant starch, oligosaccharides, especially α-galactosides, soluble and insoluble dietary fibres in children with MM.
- Effective methods to lower the fibre content of foods for children with moderate malnutrition should be identified and developed

Minerals and vitamins

All micronutrients are essential to normal functions of biological processes and human health. However, in this chapter emphasis is on those nutrients important for growth and for which the availability is affected by the food matrix or food processing and therefore considered to be of particular importance in children with moderate malnutrition.

Minerals

Iron

Iron is involved in many vital functions in the human body. First, iron is important for oxygen transport. Further, iron is essential to brain function and development and severe iron deficiency can cause retarded mental development, which may be irreversible [79]. Recently, iron
supplementation to children has been shown to increase morbidity and possibly mortality among non-iron deficient individuals in malaria endemic areas [80;81]. It is likely that the harmful effects of iron supplementation has to do with the formulation and higher amounts of iron, and it is conceivable that dietary sources of highly available iron are not harmful.

Dietary iron is present in foods in two main forms; haem iron only in foods of animal origin (high amounts in liver and red meat) and non-haem iron in both animal and plant foods, mostly in the ferric state. Haem iron and non-haem iron are absorbed through different mechanisms. Haem iron is transported into the enterocyte by the haem receptor, while non-haem iron uses the divalent metal transporter (DMT1), which means that dietary ferric iron (Fe³⁺) must be reduced to ferrous iron (Fe²⁺) before uptake [82]. Absorption of non-haem iron can be enhanced or inhibited by various dietary components and thus depends on the meal composition. An overview of dietary factors inhibiting or enhancing absorption of non-haem iron is given in Table 5 The absorption of haem iron is much higher than the absorption of non-haem iron; about 25% for haem iron and less than 10 for non-haem iron. Iron absorption is also influenced by total iron content in the diet (lower iron content increases absorption efficiency), and by iron status and physiological state of the individual (low iron stores and pregnancy increases absorption efficiency).

Milk has low iron content and the absorption is relatively poor. Older studies suggested that calcium in milk had a negative effect on iron absorption, but more recent studies have suggested that this is not the case [83;84]. Some studies have suggested that cow’s milk can induce occult intestinal bleeding in young infants which may contribute to the negative effect of milk on iron status [85]. However, it seems like the process involved in drying milk eliminates this effect, so that milk products based on powdered milk do not cause bleeding [86].
Table 5 Dietary compounds which influence the absorption of non-haem iron. a)

<table>
<thead>
<tr>
<th>Food</th>
<th>Degree of effect</th>
<th>Active substance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Inhibiting</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Whole grain cereals and maize</td>
<td>---</td>
<td>Phytate</td>
</tr>
<tr>
<td>Tea, green leafy vegetables</td>
<td>---</td>
<td>Polyphenols</td>
</tr>
<tr>
<td>Spinach</td>
<td>-</td>
<td>Polyphenols, oxalic acid</td>
</tr>
<tr>
<td>Eggs</td>
<td>-</td>
<td>Phosphoprotein, albumin</td>
</tr>
<tr>
<td>Cereals</td>
<td>-</td>
<td>Fibre</td>
</tr>
<tr>
<td><strong>Enhancing</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Liver/meat/fish</td>
<td>+++</td>
<td>“Meat factor”</td>
</tr>
<tr>
<td>Orange, pear, apple</td>
<td>+++</td>
<td>Vitamin C</td>
</tr>
<tr>
<td>Plum, banana</td>
<td>++</td>
<td>Vitamin C</td>
</tr>
<tr>
<td>Cauliflower</td>
<td>++</td>
<td>Vitamin C</td>
</tr>
<tr>
<td>Lettuce, tomato, green pepper</td>
<td>+</td>
<td>Vitamin C</td>
</tr>
<tr>
<td>Carrot, potato, beetroot,</td>
<td></td>
<td></td>
</tr>
<tr>
<td>pumpkin, broccoli, tomato cabbage</td>
<td>++/+</td>
<td>Citric, malic and tartaric acids</td>
</tr>
<tr>
<td>Fermented foods</td>
<td>++</td>
<td>Acids</td>
</tr>
</tbody>
</table>

a) Modified from [87]
Zinc
Zinc is essential to growth, synthesis and maintenance of lean body mass, and to the immune functions. Through its position in metalloenzymes zinc plays a major role in vital processes such as nucleic acid synthesis, protein digestion and synthesis, carbohydrate metabolism, bone metabolism, oxygen transport and antioxidative defence. Zinc is often the limiting growth (type II) nutrient in diets in populations with high prevalence of malnutrition [4]. Accordingly several studies have shown that zinc supplementation has a positive effect on linear growth [88]. A more recent review could not show a significant effect, but this could be because zinc might not be a limiting nutrient in all the studies included in the meta-analysis [89]. The positive effects of animal source foods on linear growth in many studies may be partly explained by widespread growth-inhibiting zinc deficiency and the high zinc content and bioavailability in animal foods. Thus, zinc is a key nutrient in diets for children with moderate malnutrition. The absorption of zinc is enhanced at low dietary intakes of zinc.

Good dietary sources of zinc include seafood, meat, nuts, and dairy products. There is a high content in whole grain cereals but due to the high content of phytic acid, a strong chelator of zinc, the bioavailability is typically low. Calcium has also a negative effect on zinc availability. Golden has recommended a nutrient density for zinc in food based diets for moderately malnourished children of 13 mg/1000 kcal. This is very high and can be difficult to achieve. It is only small freshwater fish (Table 25) that contain more than this level. Meat and large fish (Table 24, Table 25) typically have a zinc content considerably below the level of 13 mg/1000 kcal and milk a content of about 6 mg/1000 kcal. Starchy roots and legumes typically contain between 9 and 12 mg/1000 kcal. Thus the nutrient density suggested by Golden [4] can only be reached by supplements or fortification.

Phosphorus
Phosphorus (or phosphate) is part of the phospholipids, an essential functional component of cell membranes, and is part of high energy phosphate compounds like e.g. adenosine triphosphate (ATP) and creatine phosphate, the biological energy conservation molecule which is essential to all vital processes. Phosphorus is also an essential component of hydroxyapatite, the main structural bone mineral. Deficiency of phosphorus is common in malnourished children and severe hypophosphatemia is associated with increased mortality in kwashiorkor [90], although causality has not been shown. Phosphorus deficiency is also likely to cause rickets-like bone changes in malnourished children [4]. Phosphorous is likely to be a limiting nutrient in treatment of MM children.
Absorption of dietary phosphorus is high (55-70%), relatively independent of dietary composition, and does not appear to be up-regulated at low intakes. Dairy products, meat, poultry, eggs, fish, nuts, and legumes are generally good sources of highly available phosphorus. However, the main form of phosphorus from plant material is phytate which is resistant to digestion unless enzymatically degraded by phytase. Thus, phosphorus from phytate is only absorbed to a minor degree under normal conditions and the phytate fraction of phosphorous should therefore be discounted from the calculations of the total phosphorous requirements [4].

Iodine
Iodine is an essential constituent of the thyroid hormones, which are key components of development and growth. Iodine deficiency causes disorders ranging from enlarged thyroid gland (goitre) to severe irreversible mental and congenital retardation (cretinism). The risk and severity of cretinism is, however, determined by iodine deficiency during foetal life. Milder manifestations of iodine deficiency including mild mental impairment in childhood may be reversible by iodine supplementation. Most foods have naturally low content of iodine, as it depends on the iodine content of the soil. Seafoods including seaweeds are good sources of iodine. Dairy products are also good sources when cattle feed is fortified with iodine. Universal iodization of salt is recommended as the only effective way of controlling iodine deficiency, but this is a problem as salt intake should be kept low in children with MM. A better option is therefore to fortify other foods with iodine. An alternative approach in situations where fortified complementary foods are not available is to give infants and young children from 7-24 months of age an annual dose of iodized oil supplement [91].

Selenium
Selenium deficiency is prevalent and important in children with MM. Selenium protects against oxidative stress as the main antioxidant enzyme glutathione peroxidase is selenium dependent [4]. Selenium deficiency seems to play a role in development of kwashiorkor and the prognosis of the disease seems to be related to selenium status [4]. Both plant and animal source foods contain selenium in several different forms, which generally are well absorbed. But the content of selenium in both plant foods and animal source foods depends very much on the content in the soils. It is therefore not possible to give advice as to which foods are important to obtain a sufficient selenium intake.
Potassium and Magnesium

Malnourished children may have a low potassium and magnesium status, especially if they have lived on a diet with little other foods than rice or highly refined wheat and have suffered from diarrhoea, which increases the loss of these minerals [4]. Both potassium and magnesium are growth (type II) nutrients and deficiency has a negative influence on growth. Both potassium and magnesium deficiency interferes with protein utilisation; magnesium deficiency increases the risk of developing potassium depletion and supplementation with magnesium has shown to improve recovery from malnutrition [4;92].

These two minerals are mainly situated in the outer layers of cereals and the level is reduced considerably with milling. In a study of the potassium and magnesium content of food commodities used for relief feeding the potassium content in wholemeal wheat flour was about 350 to 390 mg/100g and only about 115 to 150 mg/100g in white wheat flour [93]. The corresponding figures for magnesium were about 100 and 25 mg/100g respectively. For comparison wheat soy blend (WSB) and oat meal had values close to wholemeal wheat and rice close to the values for white wheat. When comparing these values to the recommended nutrient densities suggested by Golden (K: 1400 mg/1000 kcal, Mg 200 mg/1000 kcal) wholemeal wheat flour has a potassium content of about 3/4 and a magnesium content about double these recommended densities, while white wheat flour has values far below these recommended densities.

Vitamins

Water soluble vitamins

Thiamine

Thiamine plays a central role in normal metabolism of energy, particularly carbohydrate. Thiamine is also involved in neural function. Since the body does not keep any storage capacity for thiamine it needs to be part of the daily diet. Thiamine is widely distributed in foods. Whole grain cereals, meat and fish are rich sources, whereas highly refined cereals such as polished rice are poor sources of thiamine. Thus, monotonous diets based on highly refined cereals are associated with a high risk of thiamine deficiency.

Vitamin B12

Vitamin B12 is the generic name for a group of compounds called cobalaminis. Vitamin B12 is essential for normal blood formation and neurological function. It plays an indirect but essential role in the synthesis of purines and pyrimidines, formation of proteins from amino acids, transfer of
methyl groups and for carbohydrate and fat metabolism. Through its role in the transfer of methyl groups, it is involved in the regeneration of folate. Therefore, folate and B12 deficiency may have some of the same signs of deficiency, but B12 deficiency also has neurological consequences. Vitamin B12 occurs almost exclusively in foods of animal origin. Severe deficiency can give irreversible developmental delay, including irritability, failure to thrive, apathy and anorexia [94], which may contribute to the development and manifestations of MM, and hinder its treatment.

**Vitamin C**

Vitamin C, ascorbic acid, is essential for enzymatic hydroxylation and thereby stabilisation of collagen. It is an important antioxidant and enhances absorption of non-haem iron. Scurvy, the manifestation of vitamin C deficiency, is common among those not consuming fruits or vegetables, such as refugees. The most important symptoms are nausea and poor appetite and bleeding from gums and joints, as well as joint pains and poor wound healing.

An important aspect of low vitamin C levels in the diet of children with MM is that it is associated with low iron absorption, increasing the risk of iron deficiency. Vitamin C is easily oxidized to inactive forms by exposure to air and to some degree by heat treatment. Thus, post-harvest storage and cooking of fruits and vegetables decreases the vitamin C content of the foods dramatically. The best source of vitamin C is fresh fruit.

**Fat soluble vitamins**

**Vitamin A**

Vitamin A is essential to vision, cell differentiation and immune response. It occurs in foods as two different groups of compounds. First, preformed biologically active vitamin A (retinol, retinoic acid and retinaldehyde), which is only naturally present in foods of animal origin. However, biologically active forms (retinyl palmitate) are also used to fortify foods, such as margarine, dairy products and sugar with vitamin A. Second, the provitamin A carotenoids which require enzymatic cleavage before they are converted into biologically active forms of vitamin A. These compounds occur in orange and yellow coloured fruits and vegetables and in dark-green leafy vegetables. Given the poor ability of provitamin A rich green leaves to improve vitamin A status in humans [95] the vitamin A activity of carotenoids was re-evaluated in the late 1990s [95;96] and in 2000 the US Institute of Medicine [97] revised the conversion factors and introduced a new Retinol Activity Equivalent (RAE), to replace the former retinol equivalent (RE) (Table 6). It is still debated whether the bioavailability of vitamin A in green leafy vegetables is even lower [98]. Many food composition tables use RE as the conversion factor for the carotenoids, and thus probably overestimate the contribution of vitamin A from vegetable sources. However, in 2003 *Sight and
Life supported the construction of an updated food composition table for vitamin A [99], which is available online [100].
Table 6  Provitamin A conversion factors. Amount (μg) of provitamin A equivalent to 1 μg Retinol Activity Equivalent (RAE) and to the formerly used Retinol Equivalent (RE) a)

<table>
<thead>
<tr>
<th>Compound</th>
<th>μg per μg RAE</th>
<th>μg per μg RE</th>
</tr>
</thead>
<tbody>
<tr>
<td>All-trans-β-carotene, dissolved in oil</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Dietary all-trans-β-carotene</td>
<td>12</td>
<td>6</td>
</tr>
<tr>
<td>Other dietary provitamin A carotenoids</td>
<td>24</td>
<td>12</td>
</tr>
</tbody>
</table>

a) Source [97]
The bioavailability of provitamin A depends on the food matrix and processing; bioavailability of carotenoids from raw orange fleshed fruits is higher than that of cooked yellow/orange vegetables which is higher than that of raw green leafy vegetables [101]. However, detailed information is not available to include in dietary composition software. In addition, zinc may be required for the conversion of provitamin A carotenoids to vitamin A [102].

**Vitamin D**

Vitamin D is important for normal bone metabolism but also for the immune system and other body functions. Vitamin D deficiency is associated with growth retardation and rickets and may be a risk factor of tuberculosis [103]. Sources of vitamin D are sun exposure and dietary intake [87;103]. In many areas the most important source is sun exposure. However in sunny countries factors like cultural clothing habits (especially among females) [104], skin pigmentation, and air pollution [105] may reduce the value of sun exposure as a source of vitamin D. As mentioned by Golden [4] atmospheric dust in desert areas may reflect most of the UV-B radiation except just around noon when most people are indoors. Therefore, hypovitaminosis D and rickets are very common even in many sunny countries, and people depend on intake of vitamin D either through naturally vitamin D containing foods, food fortification or supplementation.

Few food items contain more than small amounts of vitamin D. The best dietary sources are fatty fish (salmon, mackerel, herring, sardines, and oil from fish), eggs, and liver, and where available vitamin D fortified foods such as milk and margarines [87;103]. WHO recommends an intake of 10 μg vitamin D daily to avoid hypovitaminosis D [87]. For MM children the recommended vitamin D density is 13 μg per 1000 kcal [4].

**Conclusions and recommendations on minerals and vitamins**

- The content and bioavailability of minerals and vitamins are often poor in diets of children with MM and should be improved
- The bioavailability of minerals is influenced by various dietary components which may act as either an enhancer or inhibitor
- The content of phytate in foods has a strong negative effect on bioavailability of important minerals, and food processing methods that reduce the phytate content of foods should be promoted
- Fortification or supplementation may be needed to cover the high mineral and vitamin requirements of MM

**Research recommendations**

- Research is needed to clarify the role of the food matrix and food processing on mineral and vitamin availability
Bioactive Substances

Many foods also contain bioactive substances, which are substances that do not meet the definition of a nutrient, but have effects on health outcomes. Among children with MM the most important bioactive factors are milk peptides, the “meat factor” and phytoestrogens.

Milk peptides

The biological activity of some of the milk peptides has been examined in many animal studies and some human intervention studies. Most of the proposed effects of the milk peptides are related to the immune or digestive system [106].

The enzymatic digestion of protein begins in the stomach, once the proteins have been denatured by the gastric acid. It has been speculated that some of the effects of whey or other milk proteins, could be caused by peptides formed after digestion in the gastrointestinal tract [107-111].

β-Lactoglobulin constitutes about half of the total whey protein in cow’s milk, while it is absent in human milk [112]. Several biological roles of β-lactoglobulin have been suggested but are not fully proven. Aside from binding calcium and zinc it appears that β-lactoglobulin may act as a carrier for retinol. β-Lactoglobulin can protect retinol against oxidation by binding it in a hydrophobic pocket; this action furthermore promotes transport through the stomach to the small intestine where it can be transferred to another retinol protein. Another physiological role of β-lactoglobulin is its ability to bind free fatty acids thus promoting lipolysis [113].

α-Lactalbumin represents around 20% of whey protein in bovine milk and is the major protein in breast milk (20-25% of total protein). α-Lactalbumin has a high content of tryptophan and is a good source of branched chain amino acids (BCAAs), which may be the reason some studies show that whey can stimulate muscle synthesis (see section on effects of milk). Infants fed a protein reduced formula enriched with α-lactalbumin had satisfactory growth and biochemical values, suggesting adequate protein nutrition from the α-Lactalbumin-rich formula, despite its lower total protein content [114]. During the digestion of α-Lactalbumin, peptides that have antibacterial and immunostimulatory effects appear to be transiently formed, and thereby may aid in the protection against infection [115].

The concentration of immunoglobulins (Igs) is very high in colostrum but lower in mature milk. The whey fraction of milk seems to contain considerable amounts of Igs, approximately 10-15%, including IgG1, IgG2, IgA and IgM, whose physiological function is to provide various types of immunity for the calf [113]. Several studies have been focusing on the effects of treating diarrhoea with colostrum-derived bovine immunoglobulins. Positive results have
been found in children with acute rotavirus diarrhoea and in children suffering from both severe chronic Cryptosporidium parvum diarrhoea and AIDS. Both groups had significantly less stool output and reduced stool frequency and the latter group required a smaller amount of oral rehydration solution [116;117]. Cow’s colostrum also improved gut maturation and protected against necrotising enterocolitis in a model of the immature vulnerable gastrointestinal tract using preterm pigs [118].

Even though lactoferrin represents a rather small portion of whey (0.1 g/l) it may have several significant biological functions. Lactoferrin is an iron-binding protein, which can bind two ferric ions, and thereby function as a carrier of iron. Lactoferrin has important antibacterial and antiviral properties, which are mainly linked to its iron-binding capacity, thus depriving bacteria of iron essential for growth [119]. Furthermore, lactoferrin has been suggested, based on in vitro studies, to have antiviral activity against several human pathogens, including HIV [120-122]. In addition to binding iron, the peptide fragment of lactoferrin has direct bactericidal activity. Finally, lactoferrin has antioxidant activity, which which may be due to its ability to bind iron. Free iron is contributes to the generation of reactive oxygen species [113].

Whey has a high content of bioactive factors and it has been suggested that whey could have a beneficial effect on especially the immune system and on muscle tissue, but there is little evidence from vulnerable groups [23].

The “meat factor”

Meat contains the easily absorbed and highly bioavailable haem iron [123]. In addition, meat proteins (beef, veal, pork, lamb, chicken and fish) have been reported to increase non-haem iron absorption and even relatively small amounts of meat (about 50 g in adults) have been demonstrated to enhance non-haem iron absorption from a low iron availability meal with a high phytate content [124]. The enhancement of non-haem iron bioavailability is not an effect of animal protein per se, since casein and egg albumin decrease non-haem iron absorption [125]. The “meat factor” effect originates from the digestion of meat proteins to cysteine containing peptides, but the exact mechanism by which meat causes an enhancing effect on iron absorption has not yet been elucidated. The effect is believed to be caused by either a chelation of iron to minimize precipitation and interaction with absorption inhibitors like phytic acid, or by a reduction of the insoluble ferric iron to the more soluble and thereby bioavailable ferrous iron, which is more efficiently absorbed by the intestinal epithelial cells [126].
Phytoestrogens

Phytoestrogens are a diverse group of naturally occurring non-steroidal plant polyphenolic compounds with estrogenic and antiestrogenic effects because of their structural similarity with estradiol (17\(\beta\)-estradiol).

Soy and soy products are the most important source of phytoestrogens, but also other legumes, flaxseed and other oilseeds, nuts and some cereals contain compounds with phytoestrogenic properties. In soy beans the dominating compounds with phytoestrogenic properties are isoflavones, mainly genistein, daidzein, and glycitein. Lignans are the primary source of phytoestrogen found in nuts and oilseeds and also found in cereals, legumes, fruits and vegetables. Defatted soy flour contains about 60% of the isoflavones compared to full-fat flour. Soy protein isolate and soy protein concentrate contain about half the amount of total isoflavones of full-fat, roasted soy flour. Soy protein concentrate based on alcohol extraction can remove more than 90% of the isoflavones [127].

Consumption of phytoestrogens (isoflavonoids) may have some hormonal effects, although it is difficult to make firm conclusions from the studies available. It may have a negative effect on male fertility if isoflavones are taken in excess during childhood [128], by altering of the hypothalamic-pituitary-gonadal axis. However, such a hormonal effect seems to be minor [129]. Consumption of soy-based infant formula has been found to have no adverse effects on growth, development, or reproduction in some studies [130;131]. One study found that among female infants consuming soy-based formula there was a higher prevalence of infants with breast bud tissue, during the second year of life, compared with those that were breast fed and those fed cow’s milk formula. Thus, the decline in infantile breast tissue which was seen in breastfed and those fed cow’s milk did not happen in the infants fed on soy formula, but the long term implication of this finding is not known [132]. In recent comments from both the European ESPGHAN and the American Academy of Pediatrics Committees on Nutrition, it was emphasized that infant formula based on soy protein only has very limited medical indications as alternative to cow’s milk based infants formula in non breastfed infants. They also concluded that there is no firm evidence of negative effects, but the long term effects are unknown and should be investigated further [133;134].

Conclusions and recommendations on bioactive substances

- Specific milk proteins and whey protein, which contains many peptides and specific proteins could have potential relevant beneficial effects, but this has to be proven in children with MM
• The “meat factor” improves iron absorption considerably, which is an additional benefit of including meat in the diet of children with moderate malnutrition

• Children with a high intake of legumes, especially soy, will have a high intake of phytoestrogens. Although there is no firm evidence of negative effects, long term effects are unknown. The content of phytoestrogens should be measured in relevant soy containing foods and potential negative effects among children with moderate malnutrition should be studied

*Research recommendations*

• Research is needed to determine the potential benefits of adding specific milk proteins to the diets of children with MM

**Antinutritional Factors**

Antinutritional factors are food constituents which have negative impact on solubility or digestibility of required nutrients, and thereby reduce the amounts of bioavailable nutrients and available energy in the foods. Food constituents with anti-nutrient properties may also have beneficial health properties, and the significance of each anti-nutritional factor has to be considered in the context of the specific diets and the specific nutritional problems in a population.

The most important anti-nutritional food constituent in diets in low-income countries – in terms of negative nutritional impact - is phytate, primarily contributed from cereal staples and secondarily from legumes and other plant foods. Phytate forms insoluble complexes with a range of nutrients, and thereby inhibits the absorption of protein and minerals, in particular iron, zinc and calcium. Another important anti-nutritional factor in foods having negative nutritional impact in low-income countries is polyphenol compounds present in different forms in fruits, vegetables, pulses and cereals. One of the most widespread groups of polyphenols with anti-nutritional properties is soluble tannins, present in for example tea. The anti-nutritional effect of polyphenols is complex formation with iron and other metals, and precipitation of protein, which reduces absorbability. In addition, a number of more specific food components are present in some foods, and may have more isolated negative nutritional impacts in specific populations eating specific foods.

**Phytate (Phytic Acid)**

Inositol phosphates consist of an inositol ring and at least one phosphate group. Inositol hexaphosphate (IP6), which is phytate, functions as a storage compound of phosphorus in seeds,
and is essential for release of phosphorus during germination. In a dietary context, the significance of inositol phosphate as an important anti-nutrient in cereal and leguminous foods is due to this phosphorus storage function in plant seeds. Of the total phosphorus content in seeds, phytate may account for as much as 80%, and 1.5% of the dry weight. During germination, phytate is hydrolysed by endogenous phytase to release phosphate and inositol [135]. In a physiological context, phytate and other phosphorylated inositols (IP1-IP5) are not alien compounds to humans as these and other inositol deviates are widely present in very small amounts in most mammalian cells where they are involved in multiple functions related to cell signalling pathways [136]. The anti-nutritional effect of phytate in a human diet is caused by the inability of the human digestion system to degrade phytate. The phosphate groups in phytate strongly bind divalent cations of Ca, Fe, K, Mg, Mn and Zn. The complex formation of iron and other metal ions with IP4 and IP5 is weaker than with IP6, and lower inositols have insignificant inhibiting impact on mineral absorption [137;138].
Table 7 Phytate content in selected plant-derived foods

<table>
<thead>
<tr>
<th>Food</th>
<th>Phytate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(mg/g dry matter)</td>
</tr>
<tr>
<td><strong>Cereal-based</strong></td>
<td></td>
</tr>
<tr>
<td>Wheat</td>
<td></td>
</tr>
<tr>
<td>refined white wheat bread</td>
<td>0.2–0.4</td>
</tr>
<tr>
<td>whole wheat bread</td>
<td>3.2–7.3</td>
</tr>
<tr>
<td>unleavened wheat bread</td>
<td>3.2–10.6</td>
</tr>
<tr>
<td>Maize</td>
<td></td>
</tr>
<tr>
<td>flour</td>
<td>9.8–21.3</td>
</tr>
<tr>
<td>maize bread</td>
<td>4.3–8.2</td>
</tr>
<tr>
<td>unleavened maize bread</td>
<td>12.2–19.3</td>
</tr>
<tr>
<td>Rice</td>
<td></td>
</tr>
<tr>
<td>rice (polished, cooked)</td>
<td>1.2–3.7</td>
</tr>
<tr>
<td>Other cereals</td>
<td></td>
</tr>
<tr>
<td>oat porridge</td>
<td>6.9–10.2</td>
</tr>
<tr>
<td>sorghum</td>
<td>5.9–11.8</td>
</tr>
<tr>
<td><strong>Legumes and others</strong></td>
<td></td>
</tr>
<tr>
<td>chickpea (cooked)</td>
<td>2.9–11.7</td>
</tr>
<tr>
<td>cowpea (cooked)</td>
<td>3.9–13.2</td>
</tr>
<tr>
<td>black beans (cooked)</td>
<td>8.5–17.3</td>
</tr>
<tr>
<td>white beans (cooked)</td>
<td>9.6–13.9</td>
</tr>
<tr>
<td>kidney beans (cooked)</td>
<td>8.3–13.4</td>
</tr>
<tr>
<td>tempeh</td>
<td>4.5–10.7</td>
</tr>
<tr>
<td>tofu</td>
<td>8.9–17.8</td>
</tr>
<tr>
<td>lentils (cooked)</td>
<td>2.1–10.1</td>
</tr>
<tr>
<td>peanuts</td>
<td>9.2–19.7</td>
</tr>
<tr>
<td>sesame seeds (toasted)</td>
<td>39.3–57.2</td>
</tr>
<tr>
<td>soybeans</td>
<td>9.2–16.7</td>
</tr>
<tr>
<td>soy protein isolate</td>
<td>2.4–13.1</td>
</tr>
<tr>
<td>soy protein concentrate</td>
<td>11.2–23.4</td>
</tr>
</tbody>
</table>

a) Source: [139]
Phytate and lower phosphorylised inositols may be hydrolysed to lower inositol by enzymatic removal of phosphate groups. Phytases involved in the enzymatic dephosphorylation are present in plant seeds where they can mobilise the stored phosphorus, and phytases are also found in the intestines of some animals, for example rats. However, humans have evolved to have insignificant intestinal phytase activity [140], and the consumption of a phytate rich diet therefore leaves phytate largely undigested and thus phosphorus unreleased for absorption, and other important nutrients immobilised due to complex formation.
Figure 1. The effect of phytate content on non-heme iron absorption in a meal without meat or ascorbic acid, expressed relative to a phytate free meal. Based on algorithms for non-heme iron absorption [141].
The inhibiting effect of phytate on iron absorption is non-linear and the phytate content needs to be reduced to below a threshold phytate content of 100 mg \[141\], (Figure 1) or below a phytate:iron molar ratio of 1:1 \[142\] to have significant positive effect on iron absorption. The inhibiting effect of phytate on zinc absorption has recently been modelled based on data from human absorption studies \[143\], predicting that the inhibiting effect of dietary phytate on Zn absorption is linear with no upper threshold for the inhibitory effect \[144\]. Modelling absorbed Zn as a function of dietary phytate:Zn molar ratios emphasize the potential benefits of phytate reduction and Zn fortification in diets that are habitually high in phytate.

A plant-based diet has been categorised to have “moderate” zinc availability when the molar phytate:zinc ratio is between 5 and 15, and “low” zinc availability when the molar ratio exceeds 15 \[145\]. A reduction of the phytate:zinc molar ratio in a maize based diet from 36 to 17 was shown to significantly improve zinc absorption \[146\], indicating that – unlike iron – any reduction in phytate may potentially contribute to improving zinc absorption.

Various traditional processing methods can reduce the phytate content in cereals and legumes. The potential impact of traditional processing methods, thermal processing, mechanical processing, fermentation, soaking and germination (malting), on improving bioavailability of micronutrients in a plant-based diet was reviewed by Hotz & Gibson \[147\]. Soaking of cereals and legumes can promote diffusion of phytate into the soaking water. Soaking unrefined maize flour reduced phytate content by approximately 50\% \[147\], while soaking of legume seeds (peas, peanuts and pigeon peas) has been reported to reduce phytic acid by about 20\% \[148\] \[149\]. Soaking may also wash out soluble vitamins and minerals to the soaking water.

Fermentation can reduce phytate by up to as much as 90\%, depending on species and pH \[147\] as a result of the enzymatic activity of microbial phytase originating from the microflora in the fermentation culture, either present on the surface of the fermented foods (spontaneous fermentation) or added as a starter culture. Fermentation can also contribute to activating endogenous phytase in the cereal or legume being processed, especially in fermentation processes producing low-molecular organic acids such as lactic acid, as many endogenous cereal phytases have optimum activity at pH 6 or below \[135\].

The stimulation of germination of cereals and legumes will activate endogenous phytase as a step in the process of releasing the phosphorus that the plant has stored as phytate. The endogenous phytase activity is relatively higher in wheat and in other non-tropical cereals such as rye and barley, compared to tropical cereals such as maize, millet and sorghum \[150\]. Therefore, mixing for example wheat and maize in a germination process may stimulate a higher initial phytase activity and lead to higher reduction of phytate, compared to germination of pure maize.
The nutritional benefits of reducing phytate content through processing depend on the efficiency to reach a sufficiently low level of phytate to improve iron absorption. Dephytinisation will also benefit zinc absorption [142] and possibly protein utilisation.

In a community-based trial with 6-12 month old children, a complementary food based on millet, beans and peanuts was phytate reduced by soaking and germination. The phytate content was reduced by 34%, but the molar phytate:iron ratio remained high, being > 11 in the processed food. No impact on iron status in the intervention group was found [151].

In addition to reducing phytate in a plant-based diet through traditional processing technologies, the potential of reducing phytate content in cereal based foods by adding commercially produced phytase needs to be explored. Commercial phytases have been developed and are commercially available for mono-gastric animal feed. In particular in pig production it is a widely used additive to enhance protein and phosphorus absorption and thereby growth. The application of commercial phytases to foods for MM children to reduce phytate and thereby increase nutritional value, particularly mineral bioavailability, is unexplored and research is needed to clarify the potential for applications as also pointed out in the reviews by Golden [4] and by de Pee and Bloem [152]. In a recent study among women iron absorption from a whole maize porridge was increased if phytase was added to the porridge [153].

In conclusion it is important that foods used for rehabilitation of MM children should have a low content of phytate, especially if there are few or no animal source foods in the diet. This can be achieved by avoiding unrefined cereals and legumes with high phytate content and by using food processing methods that reduce the phytate content.
<table>
<thead>
<tr>
<th>Cereal or Legume</th>
<th>Morphological component</th>
<th>Distribution (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peas</td>
<td>Cotyledon</td>
<td>88.7</td>
</tr>
<tr>
<td></td>
<td>Germ</td>
<td>2.5</td>
</tr>
<tr>
<td></td>
<td>Hull</td>
<td>0.1</td>
</tr>
<tr>
<td>Wheat</td>
<td>Endosperm</td>
<td>2.2</td>
</tr>
<tr>
<td></td>
<td>Germ</td>
<td>12.9</td>
</tr>
<tr>
<td></td>
<td>Bran</td>
<td>87.1</td>
</tr>
<tr>
<td>Maize</td>
<td>Endosperm</td>
<td>3.0</td>
</tr>
<tr>
<td></td>
<td>Germ</td>
<td>88.9</td>
</tr>
<tr>
<td></td>
<td>Hull</td>
<td>1.5</td>
</tr>
<tr>
<td>Brown rice</td>
<td>Endosperm</td>
<td>1.2</td>
</tr>
<tr>
<td></td>
<td>Germ</td>
<td>7.6</td>
</tr>
<tr>
<td></td>
<td>Pericarp</td>
<td>80.0</td>
</tr>
</tbody>
</table>

a) Source: [154;155]
**Polyphenols**

Polyphenols are classified according to the polyphenolic groups. A major group with anti-nutritional significance because of inhibition of mineral absorption is the phenolic acids classified as hydrolysable (or soluble) tannins and cinnamic acid derivates (Table 9). Isoflavones are polyphenols with estrogenic effect (see section on polyphenols), and condense tannins, another group of flavonoids, have dietary significance by adding an astringent taste, as well as possessing the ability for complex formation with metals similar to soluble tannins.
Table 9 Polyphenol classes

<table>
<thead>
<tr>
<th>Polyphenol class</th>
<th>Examples of compounds</th>
<th>Examples of sources</th>
<th>Polyphenol content (mg/kg wet weight)</th>
<th>Nutritional significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phenolic acids</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Benzoic acid derivates</td>
<td>Hydrolysable (soluble) tannins e.g. gallic acid</td>
<td>Tea</td>
<td>Up to 4500</td>
<td>Inhibitor of mineral absorption</td>
</tr>
<tr>
<td>Cinnamic acid derivates</td>
<td>Caffeic acid</td>
<td>Coffee</td>
<td>350-1750</td>
<td>Inhibitor of mineral absorption</td>
</tr>
<tr>
<td></td>
<td>Chlorogenic acid</td>
<td>Fruits</td>
<td>70-310</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ferulic acid</td>
<td>Cereals</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flavonoids</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flavonols</td>
<td>Quercetin</td>
<td>Onion, Fruits</td>
<td>350-1200</td>
<td></td>
</tr>
<tr>
<td>Flavanones</td>
<td>Apigenin</td>
<td>Citrus fruits</td>
<td>200-600</td>
<td>Inhibitor of mineral absorption</td>
</tr>
<tr>
<td></td>
<td>Genistein</td>
<td>Soybeans</td>
<td>580-3800</td>
<td>Estrogenic or/and antiestrogenic effects</td>
</tr>
<tr>
<td></td>
<td>Daidzein</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Glycitein</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Isoflavones</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flavanols</td>
<td>Catechin</td>
<td>Green tea Beans</td>
<td>100-800</td>
<td>Astringent taste, inhibiting mineral absorption</td>
</tr>
<tr>
<td></td>
<td>Condensed tannins</td>
<td>Fruits Wine</td>
<td>350-550</td>
<td></td>
</tr>
<tr>
<td>(Proantocyanidins)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lignans</td>
<td>Linseed</td>
<td></td>
<td>Minor importance</td>
<td></td>
</tr>
</tbody>
</table>

a) Modified from [156]
Soluble as well as condensed tannins are located in the seed coat of dark coloured cereals, such as sorghum and millet, and in beans and other legumes. The tannin content in beans varies with colour with darker beans having a higher content. The tannin content of legumes ranges from a high value of 2000 mg/100g in faba beans to a low value of 45mg/100g in soybeans.

The anti-nutritional properties of tannins in human diets are complex formation with proteins and with a range of metals, of which complex formation with iron and zinc is the most important in the context of feeding malnourished children. The complex formation immobilises nutrients for digestion and absorption and thereby reduces the nutritional value of the food [157-159]. The tannin complex formation with proteins also inhibits the enzymatic activities of pectinase, amylase, lipase, proteolytic enzymes, β-galactosidase and those microbial enzymes involved in fermentation of cereal grains [157].

Tannins in legumes reduce ionisable iron absorption by acting as a natural iron chelating agent. About 50 mg of legume tannin binds about 1 mg of ionisable iron from food [160].

Some condensed tannins possess an astringent taste, which may contribute to a decreased intake of foods containing tannins. Tannin-rich diets have been shown to decrease growth rates in rats, chickens and ducklings [158], but to what degree this can be a problem in children is not known.

Tannins are heat stable, thus heat processing does little to reduce the tannin content in plant foods. Soaking in water or in salt solution prior to household cooking has a significant effect on reducing the tannin content (37.5-77.0%), provided the water used for soaking is discarded [158].

Black tea contains high levels of soluble tannins which have a strong inhibiting effect on iron absorption. A study in adult women quantified the inhibition of iron absorption by drinking one cup of tea with a rice meal to be 50%, and two cups reduced absorption by 66% [161]. In some populations tea with or without milk is given to infants and young children. This should be discouraged and tea should not be given to children with MM.

Other anti-nutrients

Alpha Amylase Inhibitors

Alpha amylase inhibitors are present in many cereals and legumes [162]. Amylase is necessary to hydrolyse starch and is present in the saliva and in the pancreatic secretion. Alpha amylase inhibitors reduce starch digestion and energy availability through the inhibition of amylase. Therefore, significant alpha amylase inhibitor levels in the diet may prevent required starch digestion, with the result that undigested starch is metabolised in the large intestine as soluble fibres
and turned into short chain fatty acids (SCFA) with lower energy efficiency. Alpha amylase inhibitors are relatively resistant to boiling [162]. In a study of rats fed diets with purified alpha amylase inhibitors the utilization of protein and lipids were reduced, the weight of pancreas increased and growth was reduced [163]. To what degree alpha amylase inhibitors can also impair growth in children is not known.

**Protease Inhibitors**

Trypsin and chymotrypsin are endopeptidases that break specific bonds in the middle of an amino acid chain, i.e. protein. They are secreted from the pancreas into the small intestine where they reduce large proteins into medium sized peptides which are further degraded by exopeptidases, which break off amino acids from the ends of the chain. Inhibitors of trypsin and chymotrypsin are present in most legume seeds. Among ordinary food products, soybeans are the most concentrated source of trypsin inhibitors. Trypsin inhibitors are not only restricted to their effect on trypsin, but may also inhibit other proteases [164]. High levels of protease inhibitors may result in increased size of the pancreas and in inhibition of growth [165]. Food processing can reduce the content of trypsin inhibitor activity considerably.

**Lectins (Phytohaemagglutinins)**

Lectins (also known as phytohaemagglutinins - PHAs), which are carbohydrate binding proteins or glycoproteins, are widely distributed in the plant kingdom and are found in most legumes and cereals primarily localized in the protein bodies of the cotyledon cells.

Lectins are characterized by their ability to agglutinate (i.e. to clump) red blood cells from various species of animals [165]. They have a unique property of binding carbohydrate containing molecules [163;166], thus inhibiting growth by impairing nutrient absorption [165]. In addition, about 60% of the lectins survive transit through the intestinal tract and become bound to the intestinal epithelium, causing a disruption of the brush border, atrophy of the microvilli and reducing the viability of the epithelial cells. This markedly increases nutrient requirements by the gut. Lectins can also facilitate colonisation of the gut by bacteria, including pathogens [167] and can cause bacterial overgrowth of the gut [168]. Like the protease inhibitors lectins are readily destroyed by moist heat treatment, but are quite resistant to inactivation by dry heat treatment or to degradation by digestive enzymes and bacteria [165].

**Saponins**

Saponins are a large family of structurally similar compounds present in many plants. There has been a special interest in the content in soy beans [169] because of potential use of saponins as
herbal medicine. Saponins have a bitter taste and are characterized by their haemolytic activity and foaming properties. They are hydrolyzed by bacterial enzymes in the lower intestinal tract. Saponins have negative effects on the permeability of the small intestinal mucosa and have been found to impair active nutrient transport in animal and cell models [170;171]. If this effect on the gastrointestinal tract is also relevant for children with MM is not known.

**Lysinoalanine**

Certain processing methods, such as heat and alkaline treatment produce lysinoalanine (LAL), a cross-linked aminoacid. LAL is widely distributed in cooked foods, commercial food preparations and food ingredients. LAL may exert a toxic effect via mineral binding in the renal tubules. Conversion of lysine to lysinoalanine may lead to a decrease in the digestibility of the protein and a decrease in biologically available lysine [172;173], which is important if lysine is the limiting amino acid of a diet. Particular attention has been given to sterilized milk and milk powders as low quality milk powders can contain rather large amounts of lysinoalanine [174].

**Cyanogenic glycosides**

Cyanides are found in many foods and plants, and are produced by bacteria, fungi, and algae [175;176]. Cyanogenic cassava roots (“bitter cassava”) are of particular concern [177]. Cyanide is highly toxic and must be removed. Flour of cyanogenic cassava roots can be soaked in water for activation of an enzymatic breakdown of the cyanide compounds. Consumption of insufficiently processed cassava may cause the paralytic disease known as “konzo”.

**Conclusions and recommendations on antinutrients**

- The content of anti-nutrients in plant based diets given to children with MM are likely to have a major negative impact on nutrient availability and growth
- Animal source foods have no or very low content of anti-nutrients and a diet with a high content of animal foods will therefore have a low content of antinutrients
- Phytate is the most important anti-nutrient in foods for children with moderate malnutrition because it impairs the bioavailability of iron and zinc, and its phosphorus is unreleased for absorption, which have a negative effect on growth.
- In selecting cereals, legumes and processing methods for diets for children with MM a low phytate content in the final product should be given high priority.
- Among the polyphenoles tannins is the most important anti-nutrient. Legumes and cereals with high content of tannins should not be given to children with MM. Black tea should not be given to children with MM because of the tannin content.
A number of other anti-nutrients, e.g. alpha amylase inhibitors, protease inhibitors, lectins, saponins, and lysoalanine, can also have a negative effect on growth, although there is lack of data from malnourished children.

Cyanides are highly toxic. Cassava can have high contents of cyanides and should not be given to children with MM, also because of the low content of protein and other nutrients.

Research recommendations

- Commercially produced phytase added to cereals and legumes have been very effective in improving growth in animals, especially in pigs. The potential for use in foods given to children with MM should be studied.
- There is an urgent need to perform more research on the potential negative effects of anti-nutrients in malnourished children e.g. through observational studies and animal studies. Effective processing methods should be identified and Codex Alimentarius should provide guidance on acceptable content.

Contaminants

Infants and young children, especially those being treated for wasting, have a very high energy intake per kg bodyweight and will therefore ingest large amounts of contaminants if they are given food that is contaminated. Furthermore, it is plausible that infants and young children with MM are more vulnerable to the negative effects of pesticides and heavy metals because of their rapid growth and development, but evidence for this is scarce. The use of pesticides is widespread in many low income countries, and control measures are scarce or lacking. Adulteration of foods is another aspect of contamination with potential serious effects. This recently became evident when it was discovered that melamin had been added to milk in China to increase the nitrogen content and thereby artificially increase the apparent protein content [178]. Melamine can cause urinary calculus, acute renal failure and death in infants.

Aflatoxins

Aflatoxin is a thermoresistant toxin produced by some moulds especially Aspergillus Flavus. Aflatoxin may be ingested via contaminated food, be inhaled or absorbed via the skin [179]. Exposure can result in both acute toxicity with lethal outcome or more prolonged effects like hepatocarcinosis depending on the dose ingested [179]. A possible relation between Kwashiorkor and aflatoxin exposure has been suggested [179-181]. Studies have also found an association between aflatoxin intake and growth retardation in children [179;182;183]. However, a causal relation has not been confirmed [179]. It has been suggested that aflatoxin may have immuno suppressing abilities and synergistic effects with infectious diseases like malaria and HIV [179].
It is not possible completely to avoid aflatoxin and the goal is therefore to reduce the contamination and intake as much as possible [179]. Like industrialized countries several African countries in 2003 had specific mycotoxin regulations to reduce exposure [180]. Some studies from sub Saharan Africa have shown aflatoxin concentration above the Codex Alimentarius limits in staple foods such as maize and peanuts [180]. Poisoning can still be a serious problem illustrated by the large aflatoxinosis outbreak in Kenya in 2004 resulting in many deaths [179].

High temperature and humidity gives the best environment for fungal growth, conditions that are normal in many tropical countries. With the right conditions fungi can grow in many different foods and feeds [180]. Typical staples with high risk of contamination are maize and groundnuts [179;180]. Prevention of aflatoxin exposure therefore primarily goes through good agricultural practices with better handling of crops both before and after harvest e.g. early harvesting, proper drying, removal of crops from earlier harvest, and proper storage[179;184].

**Conclusions and recommendations on contaminants**

- It is especially important that foods used for children with moderate malnutrition have low levels of aflatoxin as it is likely that these children are more vulnerable to the toxic effects.
- The levels should be at least below the levels allowed by the Codex Alimentarius.
- In programmes and teaching material aiming at treating children with moderate malnutrition it should be emphasised that foods with a high risk of contamination should be avoided.

**Food Processing**

The reasons for processing food include preservation of foods for use in times of shortage; increases shelf life; removal of toxins; removal of antinutrients, which will improve digestibility and availability of nutrients; and improvement of palatability. As part of food processing, it is also possible to fortify foods. Food preservation is done in order to reduce the content of microorganisms and enzymes, or to decrease their activity, which can be done by heating, by removal of water or by adding a preservative such as acid, sugar, or salt.

Processing will typically decrease the content of vitamins and minerals, but some methods, like fermentation and germination can increase the content of some nutrients, e.g. vitamin B and C. As processing will also decrease the content of antinutrients, it will have a positive effect on the availability of vitamins and minerals [185]. Different food processes can have different effects on a number of nutritional qualities. Mensah and Tomkins have written a comprehensive
review of how household technologies can be used to improve the nutritional value and the safety of complementary foods [186]. They have given a crude rating of how some of the most important of these household methods can have beneficial effects on complementary foods, which is shown in Table 10. However, more research is needed to fully document the potential benefits of fermentation and other food technologies in treating moderately malnourished children.

In this review focus will be on methods used for processing staple foods and legumes and how they influence the content and availability of nutrients, and the content of fibres and antinutrients, which is of special interest for selecting foods for MM children. There is a wide range of methods from industrial to household level methods, and the effect on the nutritional value depends on the kind of staple, the specific food processing methods and the intensity of treatment. Some of the most important methods and principles will be explained and examples of how they influence the nutritional value of the foods will be given. Aspects of food processing will also be covered in the sections on antinutrients and on starchy vegetable foods.
### Table 10 Benefits of household food-processing technologies a)

<table>
<thead>
<tr>
<th>Benefit b)</th>
<th>Dehulling</th>
<th>Decortication</th>
<th>Roasting</th>
<th>Soaking</th>
<th>Malting</th>
<th>Fermentation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organoleptic properties</td>
<td>-</td>
<td>+</td>
<td>+++</td>
<td>+++</td>
<td>++</td>
<td>+++</td>
</tr>
<tr>
<td>Detoxification</td>
<td>-</td>
<td>+++</td>
<td>-</td>
<td>+++</td>
<td>-</td>
<td>+++</td>
</tr>
<tr>
<td>Energy density</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>++</td>
<td>+++</td>
<td>+++</td>
</tr>
<tr>
<td>Viscosity</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>++</td>
<td>+++</td>
<td>++</td>
</tr>
<tr>
<td>Nutritive value</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>++</td>
<td>+++</td>
<td>+++</td>
</tr>
<tr>
<td>Acceptability</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>+++</td>
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</tr>
<tr>
<td>Stability</td>
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<td>+++</td>
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<tr>
<td>Safety</td>
<td>++</td>
<td>+++</td>
<td>++</td>
<td>-</td>
<td>-</td>
<td>+++</td>
</tr>
</tbody>
</table>

a) Source: [186]

b) no benefit; + below average; ++ average; +++ above average
Mechanical methods

Dried staple crops are processed into flours or powders in many different ways from traditional pounding with pestle and mortar followed by winnowing to advanced industrial milling. The overall principle is to remove the outer layers of the grains, which are either inedible or contain substances that are not wanted, because they have negative sensoric and anti-nutritional effects, are toxic, or may have a negative effect on shelf life.

Most cereals are milled into flour or meal, removing the outer layers of the grain, which reduces the nutritional value. However, it also makes the grain more resistant to degradation, because the outer layers of the grains contains fats, which are prone to rancidity. The fibre content is also highest in the outer layers and milling will therefore reduce the amount of fibre, with lower content with increasing milling. The extraction rate is the percentage of the amount of whole grain cereal which is left after milling. Because the nutrients in cereal grains are unevenly distributed, with higher content in the outer layers of especially thiamine, niacin, iron, and calcium, milling results in substantial losses of nutrients, but also in a reduction in the content of anti-nutrients like fibre, tannins and phytate (Table 8). Processing will also reduce the relative content of protein (the protein energy percentage, Table 12) as the outer layers of the grain have a higher protein content. The quality of the protein can also be reduced as the protein in the outer layers can have a high lysine content.

Dehulling or dehusking and decortication are other mechanical methods to remove the outer layers of grains. The terms are often used as synonyms, although strictly speaking dehulling refers to the removal of the outer layer only, while decortication removes more layers than only the outer layer.

The optimal degree of milling or the extraction rate, is a balance between keeping as much of the nutrients in the finished product, while at the same time removing as many of the unwanted substances, like antinutrients, as possible. It is possible that the optimal extraction rate is different for malnourished children, than for the general population, as malnourished children might be more vulnerable to the potential negative effects of antinutrients and fibres. However, as there is a lack of studies evaluating the negative effects of fibres and antinutrients in diets for children with moderate malnutrition, there is a need for studies evaluating how different processing methods of staple food influence the growth of malnourished children. Milling of the different cereals: wheat, rice, maize, sorghum and millet is described in the sections describing the cereals.
Heat processing

Heat can increase digestibility of protein, carbohydrates, and other nutrients, thereby enhancing the nutritive value of the food. It can also inactivate some of the naturally occurring enzymes, such as pectinase and lipoxygenase, in fruits and vegetables, thereby protecting against off flavours, loss of colour, and poor texture in the food product. The heat can release vitamins such as B₆, niacin, folacin, and certain carotenoids from poorly digested complexes and thereby enhance the bioavailability of these vitamins. Another advantage of thermal processing is inactivation of antinutrients in certain foods. However, thermal processing also has several adverse effects. During thermal processing and subsequent storage, thiamine and ascorbic acid are especially susceptible to depletion due to leaching and thermal degradation. In addition to Maillard reaction, a chemical reaction between an amino acid and a reducing sugar, forming a variety of molecules responsible for a range of odours and flavours, thermal processing at high temperatures can also cause other undesirable reactions to protein, such as oxidation of amino acids, and formation of new amino acid structures or dipeptides which cannot be digested or absorbed through the normal process [187].

The simplest way of heat treating cereals, legumes or tubers is to boil them, but especially legumes need boiling for a long period to be acceptable for eating, which is a resource consuming process. This is one of the reasons why cereals and legumes are often heat treated through roasting. Roasting, also called toasting, is a high-temperature dry treatment which is often used for preparing cereals and legumes for blended foods. It is typically the whole grain which is heat treated in a hot drum where the grain comes into contact with the hot wall. The process reduces some of the antinutrients and reduces the level of protease inhibitors and volatile glycosides [186]. Roasting improves flavour and enhances digestibility of the starch. The attractive “roasted” taste is because of the Maillard reactions in the outer layers of the grain. The process reduces the viscosity of porridge made from roasted flour, because of dextrinization and starch breakdown [186]. A newer method of roasting, also called “micronizing” or “infra-red roasting” brings the heat directly into the grain, somewhat similar to the microwave principle and provides a more controlled roasting.

Extrusion cooking (heating under pressure), is an energy-efficient industrial process used widely in production of blended foods, which is a much more controlled process than roasting and only takes 30-60 seconds. It is a way to “precook” cereals and legumes which will break down the starch and denature protein, thereby improve digestibility. After extrusion cooking, typically at 130-140 degrees C and under high shear, the blended food or cereal can be used as an “instant food”, which only needs to be mixed with water before eating. However, often it is advised to bring
the water to the boiling point before making the porridge or to cook the porridge or gruel for a few minutes in case the water used for mixing is contaminated.

Another important quality of extrusion treated flours is that the nutrient density is improved because of the lower viscosity, which means that less water is needed to obtain an acceptable viscosity. This is caused by dextrinization, which shortens the starch molecules. Extrusion cooking can only be used for flours or blended foods with a fat content below about 10%, if low cost dry extruders are used, but fat can be added to the product after extrusion.

Extrusion cooking has both positive and negative effects on nutritional value. Positive effects include destruction of antinutritional factors. However, extrusion cooking at very high temperatures and low water content aids Maillard reactions and reduces the nutritional value of the protein. It may also increase the formation of resistant starches, which may lead to intestinal discomfort. Furthermore, heat-labile vitamins may be lost to varying extents [188], but can be added after extrusion. Lysine is the most sensitive amino acid due to its free ε-amino group but arginine, cysteine, tryptophan, and histidine may also be affected [189]. Lysine is the limiting amino acid in most cereal proteins, and the fate of this amino acid during extrusion cooking is therefore important.

In a study with adult healthy volunteers receiving a test meal with CSB cooked for 15 min at 80 degrees C, with or without previous extrusion cooking, there was no significant effect on starch digestibility [70]. Furthermore, it was suggested that extrusion cooked foods caused increased bacterial fermentation in the colon, presumably through the solubilisation of insoluble fibres, which may depress appetite. Extrusion cooking has potential advantages when used for blended foods, but the effect of the process on gastrointestinal function in infants and young children with malnutrition needs to be investigated in more detail.

Soaking

Both whole grain and flours can be soaked. Usually the process lasts for 1-2 days, but soaking for some hours may also have beneficial effects, like reduction of phytate content [186]. Soaking of flours results in diffusion of water-soluble minerals, but also a reduction in the content of phytate [147]. The extent of the phytate reduction depends on the type of cereals or legumes, pH, and length and conditions of soaking. Soaking of unrefined maize flour can reduce phytate content by up to 50%, and most of this reduction takes place during the first few hours of soaking [147]. The content of other antinutrients such as saponins, trypsin inhibitors and polyphenols is also reduced during soaking [186].
If grains are soaked before milling it can improve flavour. If unsafe water is used for soaking enteropathogen microbes might multiply and result in a contaminated product. It is therefore important that such foods are boiled long enough to secure that pathogens are killed.

**Germination and Malting**

Legumes and grains can be soaked in water for up to 24 hours and allowed to germinate or sprout (i.e.; grow a new shoot). Grains are then dried, dehusked and milled. In this malting process some of the starch in the grains is degraded into sugars, protein quality and digestibility is improved and the content of riboflavin, niacin, and vitamin C is increased and the content of antinutrients is reduced [14;186]. In one study the content of phytate in a maize flour was reduced by 46% after germination [147]. Malting produces α-amylase which converts starch into sugars and thereby makes the porridge or gruel less thick. This is of special importance for children with MM as it allows more cereal or legume to be added thereby increasing the energy and nutrient density. Several studies have shown that the energy and nutrient intake can be improved if germinated amylase-rich flour is used for porridges or if some of this flour is added to a porridge [20;186;190]. Soaking, which is part of germination and malting processes, can add pathogens to the product, so it should be ensured that the gruel or porridge is heated sufficiently before consumption [186]. In conclusion germination and malting results in a number of beneficial effects of which the most important are increased energy and nutrient content and reduced levels of anti-nutrients.

**Fermentation**

Fermentation is one of the oldest and most effective methods of producing and preserving foods. It is a process in which microorganisms, typically lactic acid bacteria or yeast, multiply and produce a number of enzymes, like amylases, proteases and lipases, which affect taste, viscosity and nutritional value of the product. A crude overview of the beneficial effects of fermentation is given in Table 11, but some of the effects are not investigated in detail. A very important and well documented effect is on food safety as the low pH and the microorganisms produced during fermentation protect against the multiplication of pathogens. Fermentation breaks down protein to peptides or aminoacids, starch is broken down to simple sugars and phytase is produced, which breaks down phytate. Many foods like cereals, legumes, roots, fish, meat and milk can be fermented. Traditionally and in the household the process is spontaneous, initiated by the microorganisms present in the foods, but in industrial production starter cultures are often used. Fermentation of cereals and animal products are mainly done by bacteria. Moulds (multicellular fungi) are used to process cheeses and legumes, whereas yeasts (single cellular fungi) are mainly used in the fermentation of breads.
The fermentation process influences the nutritional quality of foods in a number of ways, e.g. increase in energy density and increase in the amount and bioavailability of nutrients [191] (Table 11). Fermentation of cereal gruels can improve protein digestibility. Fermentation of sorghum gruels improved protein digestibility – measured in *in vitro* systems – for gruels made of white (non-tannin) as well as colored (high-tannin) sorghum varieties. The relative improvement of protein digestibility due to the fermentation was better in the high-tannin gruels compared to gruels made of white sorghum, and also compared to maize gruels. Protein digestibility in gruel prepared with dehulled high-tannin sorghum increased from 30 to 50%, while white sorghum and maize gruels improved from 65 to 80% and 80 to 85%, respectively [191]. Fermentation of cereals has been found to improve the contents of certain B vitamins (thiamine, riboflavin and niacin). For example, fermentation increased thiamine content in sorghum from 20 to 47 μg/g, and riboflavin content in pearl millet from 0.19 to 0.36 μg/g [191]. Fermentation can induce degradation of phytate to lower inositol phosphates through microbial phytase enzymes and by activation of endogenous phytases [185]. Fermentation improves the bioavailability of iron and other minerals by reducing phytate content and by lowering the pH. In addition to the beneficial effect of direct fermentation of cereals on mineral absorption, it has been shown that the addition of small amounts of fermented vegetables (specifically carrots and onions) to a cereal meal (wheat role) almost doubled the relative iron bioavailability from the meal [191].

In conclusion fermented foods have many advantages as foods for children with MM and should be promoted where possible.
<table>
<thead>
<tr>
<th>Effects in the foods</th>
<th>Beneficial health effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breakdown of starch by amylases</td>
<td>Reduces bulk and increases energy intake</td>
</tr>
<tr>
<td>Reduction of phytic acid</td>
<td>Improved absorption of minerals and protein</td>
</tr>
<tr>
<td>Decrease in pH</td>
<td>Improved absorption of minerals</td>
</tr>
<tr>
<td></td>
<td>Improved food safety</td>
</tr>
<tr>
<td>Reduction in lactose content (only milk products)</td>
<td>Better tolerance in individuals with lactase deficiency</td>
</tr>
<tr>
<td>Increase in lactic acid bacteria</td>
<td>Better food safety</td>
</tr>
<tr>
<td></td>
<td>Improved gut integrity</td>
</tr>
<tr>
<td></td>
<td>Potential probiotic effects</td>
</tr>
<tr>
<td>Synthesis of B vitamins</td>
<td>Better vitamin B status</td>
</tr>
</tbody>
</table>
Cooking in iron pots

Cooking meals in cast iron pots has been suggested as a sustainable way of providing absorbable iron from meals. Two intervention trials with infants and young children have shown that randomisation to iron pots, compared to non-iron pots decreased the prevalence of anaemia after 8-12 months [192;193] while a more recent study showed no effect [194]. In an in-vitro study of the release of iron into a maize porridge prepared in a cast iron pot it was shown that both a low pH and the presence of organic acids increased the amount of absorbable iron released from the pot [195]. With low pH and addition of citrate as much as 26.8 mg Fe/100g porridge was released. Even with a neutral pH and with no addition of organic acids 1.7 mg/100 g porridge or 34 mg/1000 kcal was released, assuming an energy density of the porridge of 0.5 kcal/g. Thus, the use of cast iron pots for cooking foods for moderately malnourished children has the potential of providing a low cost sustainable dietary iron supply. However, the acceptability of using cast iron pots in households, the risk of providing too much iron if iron pots are used for fermented foods with low pH, and the risk of heavy metal contamination should be investigated further.

Conclusions and recommendations on food processing

- Food processing, especially of staple foods like cereals, legumes and roots, can have important beneficial effects on the nutritional value of foods given to children with moderate malnutrition
- The outer layers of grains typically have a high content of both nutrients and antinutritional factors like phytate and tannins and fibres. Processes like milling will therefore remove both nutrients and antinutrients. The optimal degree of milling is therefore a balance between keeping a high content of nutrients and removing as many of the antinutrients as possible, and it is likely that the optimal balance is different for moderately malnourished children compared to well nourished groups
- Methods like soaking, malting and fermentation increase the nutritional value of foods e.g. by reducing the content of antinutrients
- As part of food processing it is possible to fortify foods with minerals and vitamins
RELEVANT FOODS AND INGREDIENTS

Starchy Vegetable Foods

Cereals

Cereals are mainly grasses cultivated for their edible grains or fruit seeds. Cereals are the cheapest way to provide energy. In the low-income countries these foods provide ≥ 70 % of the energy intake [196]. The most important staple foods in terms of global production are maize, wheat and rice.

Cereal grains supply energy mainly as starch. They are also an important source of protein, supplying most of the protein intake in many populations. They contain from 6-14g protein per 100g dry weight and from 7 to 14 % of the energy come from protein. The amino acid composition is in most cases not optimal, typically deficient in lysine. There is some calcium and iron, but the absorption is not high. They are important sources of B vitamins, but contain no vitamin C, and no provitamin A, except for whole yellow maize. The amount of fat in cereals is generally low, with a predominance of n-6 polyunsaturated fatty acids (PUFA). Whole grains contain high levels of dietary fibre and antinutrients, which can be reduced by food processing, e.g. milling. The outer layers of the cereal grains contain the highest amounts of nutrients, fibres and antinutrients. Processing like milling will therefore typically reduce the content of all these three constituents. The degree of processing is therefore a balance between reducing the negative factors, antinutrients and fibres, which is important for young children, especially if they are malnourished, and not removing too much of the nutrients. This balance is different for each cereal and will be discussed in the sections below. It is possible that the optimal extraction rate is different for malnourished children, than for the general population, as malnourished children might be more vulnerable to the potential negative effects of antinutrients and fibres. If a large fraction of the whole grain is removed, e.g. in white wheat flour where 30-40% of the whole grain is removed, this will also influence the price of the product.

Some cereals, especially wheat, rye and barley, contain gluten, which can cause coeliac disease, a form of gluten allergy. Oats may contain very small amounts of gluten. Most other cereals, including maize, the most widely used cereal in food aid, do not contain gluten. Until recently it was believed that celiac disease, gluten intolerance, was only affecting people of European origin. However, new studies have shown that celiac disease is also a problem in populations in Southern Asia, the Middle East, North, West and East Africa and South America with wheat as the main stable diet [197]. In a study of the prevalence of celiac disease in Egypt 4.7% of children admitted with diarrhoea or failure to thrive had celiac disease [198]. Thus, gluten...
intolerance should also be considered in populations of children with moderate malnutrition in populations with a high intake of wheat. In such populations it should be considered to use diets with no gluten if the prevalence of celiac disease is high.

**Wheat**

Wheat is one of the cereals that are produced in the highest quantities in the world, and it is also the main staple food in some low-income countries, e.g. in North India and North Africa [196;199]. The protein content is about 10g/100g, i.e. the protein content constitutes about 12% of the energy. However, the quality of the protein is lower than in other cereals, with a relatively low PDCAAS (Table 2). Lysine is the limiting amino acid.

Milling of wheat increases the proportion of starch and sugars and lowers the proportion of nutrients. Mineral content decreases with the refining process and also the content of dietary fibre, protein and fat decreases significantly (Table 12 and Table 13). An example is that the content of potassium and magnesium, which are important growth (type II) nutrients, are reduced to 1/3 in white flour [93], which is discussed in more detail in the section on minerals. The refined flour contain no lignin and much less insoluble fibre than the whole grain flour [200] (Table 12). The extraction rate of whole wheat is typically 85% while white flour has an extraction rate of about 60%. In white flour most of the fibres are lost. An extraction rate about 80% is a prudent balance between not reducing the nutrient content too much and reducing the fibre content.

**Rice**

Rice is the main staple food of over half the world’s population [201]. Rice proteins have a higher content of lysine than most other cereal proteins and rice protein is considered to be of high quality, with one of the highest PDCAAS among cereals. However, rice has one of the lowest protein contents among cereals, and despite a relative high lysine content, the limiting amino acids are lysine and threonine [201;202]. Brown rice (where only the hull is removed) has higher energy content due to a higher fat content and also a higher vitamin B content, but it also has a higher content of fibre. The loss of vitamin B in milled rice, can partly be prevented by parboiling [201;202].

Parboiling is a process where the whole grain is soaked, steamed, and dried. During soaking the water soluble nutrients become more evenly distributed throughout the whole grain and are hardly removed during dehulling. During drying, the outer coat of the grain is hardened by the heat so that when the grain is stored it is more resistant to insect invasion.

Rice is rarely ground to flour. However, it is often milled into a highly refined product losing a high proportion of vitamins and other important nutrients in the process. The primary
objective in rice milling is to remove the hull and the bran with minimum breakage of the endosperm. This is achieved via cleaning, shelling or dehulling, and milling. In the brown rice only the hull is removed. The traditional method of pounding rice in a wooden mortar and winnowing it results in the loss of about half the outer layers and germ [196].

In treating children with moderate malnutrition white rice is the preferred type of rice. The phytate and fibre content is low and the content of insoluble fibres less than half than the content in brown rice.
Table 12 Macronutrients and energy in cereal staples. Values per 100g a)

<table>
<thead>
<tr>
<th></th>
<th>Energy</th>
<th>Protein</th>
<th>Carbohydrates</th>
<th>Lipids</th>
<th>Carbohydrate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total Kcal</td>
<td>E%</td>
<td>E%</td>
<td>Total g</td>
<td>Total PUFA b) w/w</td>
</tr>
<tr>
<td>Wheat</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>flour, wholemeal (85% extraction)</td>
<td>341</td>
<td>11.9</td>
<td>6.0</td>
<td>82.1</td>
<td>10.7</td>
</tr>
<tr>
<td>flour, white (60% extraction)</td>
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<td>10.8</td>
<td>4.0</td>
<td>85.2</td>
<td>9.6</td>
</tr>
<tr>
<td>Rice</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>brown, raw</td>
<td>368</td>
<td>9.7</td>
<td>7.1</td>
<td>83.2</td>
<td>9.0</td>
</tr>
<tr>
<td>white polished, raw</td>
<td>364</td>
<td>9.3</td>
<td>3.0</td>
<td>87.7</td>
<td>8.4</td>
</tr>
<tr>
<td>white parboiled, raw</td>
<td>364</td>
<td>7.8</td>
<td>1.2</td>
<td>79.8</td>
<td>7.4</td>
</tr>
<tr>
<td>Maize</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>meal, whole-grain, white/yellow f)</td>
<td>362</td>
<td>8.7</td>
<td>8.8</td>
<td>82.5</td>
<td>8.1</td>
</tr>
<tr>
<td>meal, degermed, white/yellow f)</td>
<td>369</td>
<td>8.1</td>
<td>4.5</td>
<td>87.4</td>
<td>7.3</td>
</tr>
<tr>
<td>Oat</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>rolled</td>
<td>366</td>
<td>13.7</td>
<td>15.3</td>
<td>71.0</td>
<td>13.2</td>
</tr>
<tr>
<td>Sorghum</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>whole grain e)</td>
<td>355</td>
<td>11.7</td>
<td>8.6</td>
<td>79.7</td>
<td>10.4</td>
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<tr>
<td>flour e)</td>
<td>353</td>
<td>11.3</td>
<td>6.3</td>
<td>82.4</td>
<td>10.0</td>
</tr>
<tr>
<td>Millet</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pearl, whole-grain c)</td>
<td>363</td>
<td>12.0</td>
<td>12.3</td>
<td>75.7</td>
<td>11.0</td>
</tr>
<tr>
<td>Pearl, flour c)</td>
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<td>9.8</td>
<td>7.4</td>
<td>82.8</td>
<td>9.0</td>
</tr>
<tr>
<td>Finger, whole-grain c)</td>
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<td>7.1</td>
<td>4.0</td>
<td>88.9</td>
<td>6.0</td>
</tr>
<tr>
<td>Finger, flour c)</td>
<td>332</td>
<td>6.6</td>
<td>2.2</td>
<td>91.2</td>
<td>5.5</td>
</tr>
</tbody>
</table>

a) Source: [28], unless otherwise noted.
b) PUFA: poly-unsaturated fatty acids, E%: Energy percent
d) Insoluble fibre roughly is equivalent to crude fibre, whose definition is based on outdated analysis method: edible part of plant insoluble in strong acids and alkalis.
e) Source: [203]
f) Source: [27].
Table 13 Energy and nutrient densities in cereal staples a)

<table>
<thead>
<tr>
<th>Energy</th>
<th>Nutrient density per 1000 Kcal</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total Kcal/100g</td>
</tr>
<tr>
<td>--------</td>
<td>-----------------</td>
</tr>
<tr>
<td>Wheat</td>
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<tr>
<td>brown, raw</td>
<td>368</td>
</tr>
<tr>
<td>white polished, raw</td>
<td>364</td>
</tr>
<tr>
<td>white parboiled, raw</td>
<td>363</td>
</tr>
<tr>
<td>Maize</td>
<td></td>
</tr>
<tr>
<td>meal, whole-grain, white/yellow c)</td>
<td>362</td>
</tr>
<tr>
<td>meal, degemermed, white/yellow d)</td>
<td>369</td>
</tr>
<tr>
<td>Oat</td>
<td></td>
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<tr>
<td>rolled</td>
<td>366</td>
</tr>
<tr>
<td>Sorghum</td>
<td></td>
</tr>
<tr>
<td>whole grain d)</td>
<td>355</td>
</tr>
<tr>
<td>flour d)</td>
<td>353</td>
</tr>
<tr>
<td>Millet</td>
<td></td>
</tr>
<tr>
<td>Pearl, whole-grain d)</td>
<td>363</td>
</tr>
<tr>
<td>Pearl, flour d)</td>
<td>365</td>
</tr>
<tr>
<td>finger, whole-grain d)</td>
<td>336</td>
</tr>
<tr>
<td>flour d)</td>
<td>332</td>
</tr>
</tbody>
</table>

a) Source: [28] unless otherwise noted.
b) Values from [4]
c) Source: [27]
d) Source: [203]
e) Source: [142]
f) Source: [150]

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Maize

Maize, or corn, is used as a staple food mainly in the Americas and in Africa. The major nutritional component in maize is starch in the form of amylose and amylopectin. The maize kernel contains about the same amount of protein as other cereals but with a lower content of lysine and tryptophan. The fat content is high, about 9 % of the energy in wholegrain maize. Maize oil has a high content of polyunsaturated fatty acids mainly linoleic acid (24 %) and thereby a high n-6/n-3 fatty acid ratio [204]. The wholegrain maize has a low content of niacin, even compared to wheat and rice. Furthermore, it is in a form with reduced availability [196]. In South America maize is often treated with lime water, which makes niacin better available.

In the late 1930s Cicely Williams made the first description of kwashiorkor and described that it was associated with a maize diet [205]. However, since most of the children had a history of deficient breastfeeding and only got supplementary food with maize, it may not have been a characteristic of maize that caused kwashiorkor in that setting.

Milling of maize reduces the nutritional value as it does in other cereals. The milling of maize gives a variety of products and there are two methods when milling maize; dry and wet milling [204]. The wet milling produces starch, syrups and dextrose for use in the food industry. The most common process used in low-income countries is dry milling. At dry milling the hull and germ are stripped from the endosperm and can be totally separated from the endosperm [206]. Degermed and dehulled maize has an extraction rate of 60%, which almost doubles the price compared to wholemeal flour. Traditional methods using stones or pestle and mortar are still a common practice in many low-income countries. With these methods the grains lose some of its outer coats, but retain some of the lipid rich outer layers. Because of the fat content the products become rapidly rancid and milling has to be done frequently [207].

Oat

Oat is mainly grown in cold areas and is not considered an important crop in the diets of most low-income countries. Oats have a high nutritional value. The protein content is higher (13 g/100g) than in maize, rice and wheat, and it also has a high lysine content and thereby a high PDCAAS. However, there is also a considerable quantity of phytic acid. The lipid concentration of oat is higher than in other cereals with a favourable ratio of unsaturated to saturated fatty acids compared to other cereals. Oat is appropriate for children with MM, but due to price and availability it is often not a realistic option.
Sorghum and Millet

Sorghum and millets are groups of grasses with an ancient history of cultivation in Africa and Asia (Table 14). They are relatively drought resistant crops and suitable for production under difficult agronomic conditions. Sorghum and millets for human consumption are mostly grown in Africa and India, though the production is declining, being replaced by maize and rice. Sorghum and millets are often grown for subsidence use and therefore important crops for local food security in some arid and semi-arid regions. Sorghum and millets are used in a range of traditional foods and beverages, such as thin and stiff porridges, unleaved flatbreads and beverages.
Table 14 Origins and common names of sorghum and millets a)

<table>
<thead>
<tr>
<th>Crop</th>
<th>Common names</th>
<th>Suggested origin</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Sorghum bicolor</em></td>
<td>Sorghum, great millet, guinea corn, kafir corn, aura, mtama, jowar, cholam.</td>
<td>Northeast quadrant of Africa (Ethiopia-Sudan border)</td>
</tr>
<tr>
<td><em>Pennisetum glaucum</em></td>
<td>Pearl millet, cumbu, spiked millet, bajra, bulrush millet, candle millet, dark millet</td>
<td>Tropical West Africa</td>
</tr>
<tr>
<td><em>Eleusine coracana</em></td>
<td>Finger millet, African millet, koracan, ragi, wimbi, bulo, telebun</td>
<td>Uganda or neighbouring region</td>
</tr>
<tr>
<td><em>Setaria italica</em></td>
<td>Foxtail millet, Italian millet, German millet, Hungarian millet, Siberian millet</td>
<td>Eastern Asia (China)</td>
</tr>
<tr>
<td><em>Panicum miliaceum</em></td>
<td>Proso millet, common millet, hog millet, broom-corn millet, Russian millet, brown corn</td>
<td>Central and eastern Asia</td>
</tr>
<tr>
<td><em>Panicum sumatrense</em></td>
<td>Little millet</td>
<td>Southeast Asia</td>
</tr>
<tr>
<td><em>Echinochloa crus-galli</em></td>
<td>Barnyard millet, sawa millet, Japanese barnyard millet</td>
<td>Japan</td>
</tr>
<tr>
<td><em>Paspalum scrobiculatum</em></td>
<td>Kodo millet</td>
<td>India</td>
</tr>
</tbody>
</table>

a) Source: [208]
There are white and colored varieties of sorghum and millets species. The colored varieties contain tannins and have some agronomic advantages because they are more resistant to bird and pest attacks, but the tannins have negative impact on the nutritional value because of the anti-nutrient properties.

Millets are different species of small seeded grasses of which the major species for human consumption are pearl millet (*Pennisetum glaucum*) and finger millet (*Eleusine coracana*). The nutritional quality including protein and fat contents varies with the species and varieties. Both sorghum and millet species in general have high contents of fibers. The total dietary fibre in millets was reported to 17-20 %, and 14 % in sorghum[208].

Industrially and home-based processing of sorghum and millets include mechanical milling to obtained dehulled, refined flour. Milling of sorghum removes 10-30 % of the original weight. Traditional processing of sorghum and millets includes fermentation, soaking and malting/germination, which can contribute to improve the nutritional quality by reducing contents of tannins and fibers.

Sprouts of germed sorghum contain a cyanogenic glucoside, which can be hydrolysed to highly toxic cyanide (HCN) [209] and the fresh shoots and roots of germinated sorghum must therefore never be consumed.

**Quinoa**

Quinoa is grown as a crop primarily for its edible seed. It is a pseudo-cereal rather than a true cereal as it is not a grass. Its leaves are also eaten as a leaf vegetable. Quinoa originates from South America and is still mainly grown there [210]. Quinoa has a balanced content of essential amino acids and thereby a high protein quality [211]. It is also a source of vitamin E, thiamine, iron, zinc and magnesium [212;213]. Quinoa has a coating of bitter-tasting saponins, which can be removed by soaking [214].

**Teff**

Teff is mainly grown in Ethiopia and Eritrea, and to a lesser degree in India and Australia. The grain has a high content of several nutrients, i.e. high calcium content, and high content of phosphorus, iron, copper, and thiamine. Teff also has a good amino acid composition and has lysine levels higher than wheat. In Ethiopia and Eritrea teff is mainly used in enjera, a fermented thin and flat pancake, which is mainly consumed by adults. The high content of important nutrients combined with the advantages of fermentation (Table 11 in section on fermentation) makes enjera
a potentially valuable food for malnourished children, but the tradition is to feed infants and young children porridge and pancakes made from unfermented teff. Teff is considerably more expensive that other cereals.

Conclusions and recommendations on cereals

- Cereals are important ingredients in diets for children with MM as they provide easily available and low cost energy, protein and important nutrients
- In choosing the best cereal types for treating children with MM the content of nutrients, fibres and antinutrients, especially phytate, should be taken into consideration
- A high extraction rate will reduce the content of fibres and anti-nutrients, but also the content of nutrients. Thus, the optimal extraction rate is a balance that differs according to type of cereals and target population
- White rice, wheat flour with 85% extraction rate and maize flour with a 60% extraction rate are prudent choices for feeding children with MM

Legumes and Pulses

Legumes are plants from the family Fabaceae or fruits of these plants. Well-known legumes include peas, beans, and peanuts. FAO has defined the term pulses for crops harvested solely for the dry grain. Thus, this excludes green beans and green peas, as they are considered vegetable crops. Crops that are mainly grown for oil extraction (oilseeds e.g. peanuts and soybeans) are also excluded. Legumes play an important role in the diet in Asia, India, South and Middle America and to some extent in Africa.

Legumes have a high nutritional quality. The protein content is high, typically from 20 to 35 g/100g, or a protein energy percentage from 20 to 30. The quality of the protein is not high because of a low content of methionine. The lysine content is high compared to cereals and therefore legumes complement the low content in cereals resulting in a high PDCAAS in foods with both cereals and legumes. The fat content is low, about 1-3 %, with the exception of whole peanut and soybean, which contain about 43 and 18g fat/100 g respectively. The total content of fibre is generally high typically around 5-15 g/100 g dry weight, of which 4-5 g/ 100g are insoluble fibres (Table 15). The content of phytate is high in legumes, at the same level as in wholegrain cereals (Table 13 and Table 16). However, in cereals the phytate is mainly located in the outer layers and can more easily be removed during processing, which is not the case with legumes. Therefore the contents of phytate is higher in legumes such as for example shown in an analysis of
complementary foods from Indonesia [215]. The levels were typically three to four times as high in legumes compared to cereals. Coloured legumes also have high levels of polyphenols.

Legumes often contain high amounts of indigestible oligosaccharides (stachyose and raffinose) which are rapidly fermented in the colon and can cause undesired flatulence [216]. This gas production may play a role in the acceptability of legumes, including soy products as a major food source for humans [217-220].

**Lentils**

Lentil is a plant of the legume family, with lens-shaped seeds. Lentils are used to make daal, a traditional dish with cooked lentils. Lentils can be white, yellow, red, green, brown and black. Red, yellow and white lentils have their skins removed, i.e. they are decorticated. Some lentils contain a toxin which can cause Latyrism, a neurological condition with paralysis [221]. The amount of toxin can be reduced by soaking, heating and fermentation.
Table 15 Macronutrients and energy in starchy roots and legumes. Values per 100g a).

<table>
<thead>
<tr>
<th></th>
<th>Energy</th>
<th>Protein</th>
<th>Lipids</th>
<th>Carbohydrate</th>
<th>Total</th>
<th>PUFA b)</th>
<th>n6:n3 w/w ratio</th>
<th>Total</th>
<th>Dietary fibre c)</th>
<th>Insoluble fibre d,e)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Kcal</td>
<td>E%</td>
<td>E%</td>
<td>E%</td>
<td>g</td>
<td>G</td>
<td>g</td>
<td>g</td>
<td>g</td>
<td>g</td>
</tr>
<tr>
<td><strong>Legumes</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kidney bean a)</td>
<td>339</td>
<td>28.3</td>
<td>4.5</td>
<td>67.2</td>
<td>24.0</td>
<td>1.7</td>
<td>-</td>
<td>57.0</td>
<td>-</td>
<td>4.0</td>
</tr>
<tr>
<td>Mung bean, raw, dry</td>
<td>312</td>
<td>27.0</td>
<td>3.3</td>
<td>69.7</td>
<td>24.2</td>
<td>1.3</td>
<td>-</td>
<td>62.6</td>
<td>15.0</td>
<td>4.6</td>
</tr>
<tr>
<td>Brown bean, dry</td>
<td>314</td>
<td>21.8</td>
<td>5.2</td>
<td>73.0</td>
<td>18.9</td>
<td>2.0</td>
<td>-</td>
<td>63.4</td>
<td>17.8</td>
<td>-</td>
</tr>
<tr>
<td>Red lentil, raw, dry</td>
<td>361</td>
<td>29.5</td>
<td>7.1</td>
<td>63.4</td>
<td>27.3</td>
<td>2.9</td>
<td>1.1 f)</td>
<td>58.5</td>
<td>6.2</td>
<td>4.0</td>
</tr>
<tr>
<td>Brown lentil, raw, dry</td>
<td>340</td>
<td>28.0</td>
<td>5.0</td>
<td>67.0</td>
<td>25.1</td>
<td>2.0</td>
<td>0.5 f)</td>
<td>60.1</td>
<td>11.2</td>
<td>4.0</td>
</tr>
<tr>
<td>Soy flour, full fat</td>
<td>449</td>
<td>31.6</td>
<td>42.5</td>
<td>25.9</td>
<td>37.2</td>
<td>22.2</td>
<td>12.6</td>
<td>7.1</td>
<td>30.5</td>
<td>-</td>
</tr>
<tr>
<td>Soy flour, defatted f)</td>
<td>375</td>
<td>45.4</td>
<td>20.0</td>
<td>34.6</td>
<td>45.5</td>
<td>8.9</td>
<td>3.9</td>
<td>-</td>
<td>34.9</td>
<td>16.0</td>
</tr>
<tr>
<td>Peanut, dry</td>
<td>557</td>
<td>16.7</td>
<td>64.3</td>
<td>19.0</td>
<td>24.9</td>
<td>42.7</td>
<td>14.5</td>
<td>∞</td>
<td>28.4</td>
<td>7.7</td>
</tr>
<tr>
<td><strong>Starchy roots</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cassava, raw</td>
<td>120</td>
<td>10.0</td>
<td>2.9</td>
<td>87.1</td>
<td>3.1</td>
<td>0.4</td>
<td>0.1</td>
<td>1.9</td>
<td>26.9</td>
<td>2.5</td>
</tr>
<tr>
<td>Sweetpotato, raw</td>
<td>71</td>
<td>6.9</td>
<td>3.6</td>
<td>89.6</td>
<td>1.3</td>
<td>0.3</td>
<td>0.1</td>
<td>5.5</td>
<td>17.0</td>
<td>3.0</td>
</tr>
<tr>
<td>Yam, raw</td>
<td>119</td>
<td>5.0</td>
<td>1.5</td>
<td>93.5</td>
<td>1.5</td>
<td>0.2</td>
<td>0.1</td>
<td>5.3</td>
<td>27.9</td>
<td>1.0</td>
</tr>
<tr>
<td>Potato, raw</td>
<td>82</td>
<td>9.1</td>
<td>3.2</td>
<td>87.7</td>
<td>1.9</td>
<td>0.3</td>
<td>0.2</td>
<td>0.8</td>
<td>18.3</td>
<td>1.4</td>
</tr>
<tr>
<td><strong>Other</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plantain, raw f)</td>
<td>122</td>
<td>3.8</td>
<td>2.4</td>
<td>93.8</td>
<td>1.3</td>
<td>0.4</td>
<td>0.1</td>
<td>-</td>
<td>31.9</td>
<td>2.3</td>
</tr>
</tbody>
</table>

a) Source: [28] unless otherwise noted.
b) PUFA: poly-unsaturated fatty acids
d) Insoluble fibre roughly is equivalent to crude fibre, whose definition is based on outdated analysis method: edible part of plant insoluble in strong acids and alkalis.
e) Source: [203]
f) Source: [27]
Table 16 Nutrient densities in starchy roots and legumes

<table>
<thead>
<tr>
<th></th>
<th>Energy</th>
<th>Nutrient density per 1000Kcal</th>
<th>Phytate ratio b) (molar)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total Kcal/100g</td>
<td>Folates μg</td>
<td>Vit. B1 mg</td>
</tr>
<tr>
<td>Recommended nutrient density per 1000 kcal c)</td>
<td>220</td>
<td>0.6</td>
<td>600</td>
</tr>
<tr>
<td><strong>Legumes</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kidney bean d)</td>
<td>339</td>
<td>-</td>
<td>1.5</td>
</tr>
<tr>
<td>Mung bean, raw, dry</td>
<td>312</td>
<td>1041</td>
<td>1.2</td>
</tr>
<tr>
<td>Brown bean, dry</td>
<td>314</td>
<td>446</td>
<td>1.1</td>
</tr>
<tr>
<td>Red lentil, raw, dry</td>
<td>361</td>
<td>565 e)</td>
<td>1.4 e)</td>
</tr>
<tr>
<td>Brown lentil, raw, dry</td>
<td>340</td>
<td>1409 e)</td>
<td>2.6 e)</td>
</tr>
<tr>
<td>Soy flour, full fat</td>
<td>449</td>
<td>1782</td>
<td>1.7</td>
</tr>
<tr>
<td>Soy flour, defatted e)</td>
<td>375</td>
<td>813</td>
<td>2.9</td>
</tr>
<tr>
<td>Peanut, dry</td>
<td>557</td>
<td>190</td>
<td>1.6</td>
</tr>
<tr>
<td><strong>Starchy roots</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cassava, raw</td>
<td>120</td>
<td>183</td>
<td>1.9</td>
</tr>
<tr>
<td>Sweetpotato, raw</td>
<td>71</td>
<td>199</td>
<td>1.0</td>
</tr>
<tr>
<td>Yam, raw</td>
<td>119</td>
<td>193</td>
<td>0.9</td>
</tr>
<tr>
<td>Potato, raw</td>
<td>82</td>
<td>441</td>
<td>0.7</td>
</tr>
<tr>
<td><strong>Other</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plantain, raw e)</td>
<td>122</td>
<td>180</td>
<td>0.4</td>
</tr>
</tbody>
</table>

a) Source:[28], unless otherwise noted.
b) Phytate (mg/100g) is based on the sum of IP5 and IP6.
c) Values from [4]
d) Source: [203]
e) Source: [27]
f) Source: [215]
g) Source: [150]
Beans

Beans are large plant seeds from the family *Fabaceae*. There is a great variety of bean types that are produced in large parts of the world. A group of legumes is grams and includes pigeon pea, chick pea, green gram and mung bean [196].

The protein content of beans is between 20 and 30 %. The PDCAAS is reasonably good, although their overall value is reduced by their lower digestibility [222]. Beans are generally very low in fat, containing about 2-5 % of energy as fat, and the dietary contribution of beans to the intake of n-3 fatty acid, due to the content of $\alpha$-linolenic acid intake is generally minor [223]. Beans are an excellent source of folate. Even though beans have a relatively high content of both calcium and iron, beans are not a very good iron source, because of low bioavailability from legumes [224-227]. Beans provide a large amount of dietary fibre.

Beans contain several antinutrient factors, of which the most important are trypsin inhibitors, phytate and lectins. Phytate content of beans is between 1 % and 2 % and contributes to the poor mineral bioavailability of beans [228;229].

Soybean

Soybeans are an important crop, providing primarily a high content of oil and protein. Soybeans appear in various colours: black, brown, blue, green and yellow. The oil and protein content together account for about 60 % of the weight of dry soybean flour; protein 37 % and oil 22 % (Table 15).

The protein content is of high quality. It contains all the essential amino acids. With the exception of the sulphur amino acids, cysteine and methionine, in which soybean is deficient, other essential amino acids are present in sufficient quantities; noteworthy is the high amount of lysine which distinguishes soybean from other legumes and cereals [230;231], and provides soy protein with a high PDCAAS. For this reason, soy is a good source of protein, especially for those living on a diet low in animal source foods.

The oil content is of high quality, as soy oil contains a high proportion of unsaturated fatty acids with a high content of the n-3 fatty acid $\alpha$-linolenic acid and thereby a favourable n-6/n-3 PUFA ratio of about 7. The fatty acid content of soy is discussed in more detail in the section on oils.

On average dry soybeans contain about 35 % carbohydrates. The insoluble carbohydrates in soybeans include cellulose, hemicellulose, pectin and a trace amount of starch. Soybeans contain both water-soluble and fat-soluble vitamins. The water-soluble vitamins are
mainly thiamine, riboflavin, niacin, pantothenic acid, and folic acid. Soybeans also contain vitamin C but the amount is negligible in mature soybeans, although it is present in measurable amounts in both immature and germinated seeds [231]. The fat-soluble vitamins in soybeans are vitamins A and E, with essentially no vitamins D and K. Vitamin A is mainly present as the provitamin β-carotene and the content is negligible in mature seeds.

As in most legumes, there is an abundance of potassium but not sodium, and soybeans are a very good source of phosphorus, although a significant proportion of it is present as phytic acid phosphorus which has only partial biological availability. Soybeans are also a good source of calcium and magnesium but poor in iron. The amounts of zinc, iron and iodine are minimal [231]. Soybeans contain antinutritional factors of which the most important are protease inhibitors, lectin and phytates.

A range of soy products are used for vulnerable and undernourished populations. The most common products are whole soybeans or grits, full fat soy flour, and defatted soy flour [232]. In CSB non-dehulled and dehulled soybeans and defatted and toasted soy flour has been used [152]. Other more refined products are soy protein concentrates and soy protein isolates, the latter used in infant formula. The difference between defatted soy flour, soy concentrates and soy isolates is not only the carbohydrate content, which is 32 %, 21 % and 3 % respectively, but also the content of fiber and anti-nutrients is reduced, but important quantities are left even in soy isolates [127;218;233;234].

In conclusion soy has an exceptionally high content of both protein and fat. The quality of protein is high with a balanced amino acid composition and thereby a high PDCAAS and the quality of fat is also good with a relatively high contribution from n-3 PUFA and thus a favourable n-6/n-3 fatty acid ratio. On the other hand soy also contains high levels of antinutrients, especially phytate, and high levels of phytoestrogens (see section on phytoestrogens). There is a lack of studies on the potential negative effects of the antinutrients in soy in malnourished infants and young children. Studies of growth in weanling pigs have shown that growth is better on a milk based diet, compared to a corn-soy diet [23]. But whether that is due to beneficial effects of milk or antinutritional effects of the soy and corn is not known. There is an urgent need to perform studies of the effect of different preparations of soy with different content of anti-nutrients to evaluate the effect on growth.

**Peanut**

The peanut is also known as groundnut and is one of the most nutritious seeds and one of the world’s most popular legumes/pulses. In Africa peanuts are prepared as fresh boiled peanuts or they
are roasted. They may also be ground or milled and ground peanut is often available at markets to prepare peanut sauce [196;235].

With more than 40 % fat, peanuts contain more fat than other legumes. The protein content is about 25%, but peanuts are deficient in lysine and methionine. The amount of carbohydrate is relatively low about 28%. Peanuts have little or no carotene, but are a good source of vitamin E, niacin and folate [236]. The fatty acid composition is discussed in the section on oils. Peanuts have higher levels of phytate that most other legumes (Table 7 and Table 15) and also contain alpha galactosides.

Conclusions and recommendations on legumes and pulses

- Legumes and pulses are important foods for children with MM because they have a high content of protein with an aminoacid composition that complements the aminoacid profile of cereals
- The content of fibers and antinutrients is high and optimal processing to reduce the amounts is important
- Soybeans are used widespread as a commodity with a high protein content and quality at a reasonable price. However the content of fibers and phytate differs considerable between different soy bean products
- Soybeans have a high content of fat with a high content of PUFA and a optimal n-6/n-3 balance

Research recommendations

- There is a need to examine the potential growth inhibiting effect of different soy preparations with different degrees of processing

Roots

Roots provide primarily energy in the human diet in the form of carbohydrates. In low-income countries the main nutritional value of roots is their potential ability to provide one of the cheapest sources of energy in the form of carbohydrates. Both protein and fat content is very low.

Cassava

Cassava is a starchy root and an essential part of the diet of more than half a billion people. Cassava is a plant originally from South America but now grown in many places. It is known under different names as manioc or tapioca. It is drought resistant, needs little attention and gives a high yield. Both the tubers and the leaves are used as food sources. The tubers are an important staple food in
many low-income countries of Africa, South and Central America, India and Southeast Asia, providing a cheap carbohydrate source. About 90% of the energy content in cassava comes from carbohydrates, mainly starch. Cassava is deficient in protein, with only about 3% of the energy coming from protein and only 1% from fat. Cassava species contain varying amounts of cyanogenic glycoside, which is toxic, can cause the paralytic disease Konzo and can interfere with the function of the thyroid gland and cause goitre [177;237]. The content can be reduced by soaking or boiling, but fermentation is more effective. Cassava leaves have a high content of carotene, vitamin C, iron and calcium. The leaves contain more protein than the tubers, but they lack the methionine [196;238].

Potatoes and sweet potatoes
Potatoes belong to the nightshade (Solanaceae) family, and have high protein content (9 E%) with a high protein quality (PDCAAS, Table 2) higher than any of the cereals and other roots. The content of fibres is low and the content of vitamin C and potassium high. During the last decade, there has been a marked increase in potato production in many developing countries. Because of the potential role of potato production in food security and poverty reduction UN and FAO declared 2008 as the year of the potato (www.potato2008.org). Sweet potatoes are starchy roots belonging to the bindweed family (Convolvulaceae), which are widely grown as staple foods in parts of Africa and Asia. Sweet potatoes have the same energy content as potatoes, but a lower protein content equivalent to about 7 E%. The yellow forms of sweet potato (Orange Flesh Sweet Potatoes (OFSP)) contain higher amounts of provitamin A, β-carotenoids than white forms, and have been promoted as a dietary supplement to improve vitamin A status in vitamin A deficient children [239;240].

Plantain
Plantain is not a root, but a form of banana and thereby a fruit, but is often classified with starchy roots as it has a nutritional composition close to that of starchy roots. They contain more starch than bananas and are either cooked or fried or made into a flour after sun drying [196].

Conclusions and recommendations on roots
- Roots are typically cheap sources of energy, but the protein and fat content is low and they are therefore not optimal as foods for children with MM
- Potatoes are valuable foods with a high content and quality of protein and with a low content of fibres and phytate
Vegetables

A vegetable is not botanically defined, as it may be any edible part of a plant, such as the root, stem, leaves or fruit. Many vegetables, such as carrot, onion, tomato, pumpkin, okra, aubergine, and green peas can be valuable ingredients in diets for children with MM. In addition to the energy and nutrients they provide, they bring taste, colour and variability to the diet. Although vegetables typically shrink when cooked they are often not very energy dense and can contribute to the bulkiness of the meal. They may also contain considerable amounts of fibre, which is part of the bulk problem. Many vegetables contain important amounts of micronutrients, especially provitamin A and vitamin C, and iron. Although bioavailability of minerals can be low because of antinutrients, the high amounts of vitamin C may improve the mineral bioavailability of the whole meal. Vegetables, like green leaves and fruits, can be grown in home gardens or gathered from fields or bushes at village level. Some vegetables, such as tomatoes, can be sundried and later used in cooked meals. Vegetables may therefore be affordable and valuable ingredients in diets for children with MM.

Conclusions and recommendations on vegetables

- Many vegetables are affordable and nutritionally valuable ingredients in diets for children with MM

Green leafy vegetables

Dark green leafy vegetables such as kale, spinach, and leaves of cassava, pumpkin, amaranth, and taro are widely available and consumed as part of the normal diet in many populations. Green leafy vegetables are rich sources of mainly provitamin A and vitamin C, iron and calcium (Table 17 and Table 18) They are almost always cooked before consumption whereby they shrink in volume and become more nutrient dense. However, cooking may affect the bioavailability and activity of the nutrients. Cooking destroys 50-80% of the vitamin C but improves the bioavailability of beta-carotene [98].

Even though the conversion of provitamin A carotenoids is less effective than previously believed [98], daily consumption of green leafy vegetables is still a valuable source of vitamin A even with low intake of dietary fat [241]. Since green leafy vegetables can be grown at home at low cost they may serve as a reasonable alternative to vitamin A rich animal source foods. Home gardening of green leafy vegetables combined with nutrition education in rural South Africa
did actually improve the vitamin A status of 2 to 5 year old children compared to children in a control village [242].

The iron content of most green leafy vegetables is relatively high although the bioavailability of iron is compromised by a high content of tannins and oxalates [243].

Overall, consumption of green leafy vegetables improves the nutrient quality of cereal based diets, although the bioavailability of vitamin A as well as iron is low.

**Moringa leaves**

The tropical drought resistant tree *Moringa oleifera* is native to India but has been introduced to the African and South American continents. The leaves are consumed raw, cooked as other green leaves or as a dried, concentrated powder. The Moringa is suitable for home gardening, as it is easy to grow and its fresh leaves can be harvested continuously. It has been claimed to have an unusually high content of calcium, iron, and vitamin A [244] and high quality protein, and a low content of antinutrients such as tannins and oxalates [245]. Moringa leaves have therefore been promoted as a potential low cost high quality food. Published data on the nutrient content of Moringa leaves are, however, inconsistent [244;246;247], probably reflecting different pre- and postharvest procedures, varieties, leaf age, etc. There is limited information on the bioavailability of nutrients from Moringa leaves, although they were effective in improving vitamin A status in depleted rats [248]. Systematic nutrient analyses and human intervention trials assessing the effects of consumption of Moringa leaves are needed before the potential effects of the Moringa tree can be estimated.

**Conclusions and recommendations on green leafy vegetables**

- Green leafy vegetables contain iron and provitamin A and can be valuable ingredients in diets for moderately malnourished children

*Research recommendations*

- Leaves from the Moringa tree may be rich in minerals and provitamin A, but the actual content and bioavailability needs to be assessed. The value for children with MM should be examined further
Table 17 Macronutrients and energy in selected green, leafy vegetables. Values per 100 g raw, edible portion a)

<table>
<thead>
<tr>
<th></th>
<th>Energy kcal</th>
<th>Protein g</th>
<th>Lipid g</th>
<th>Protein E%</th>
<th>Lipid E%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pumpkin leaves</td>
<td>19</td>
<td>3.15</td>
<td>0.40</td>
<td>68</td>
<td>19</td>
</tr>
<tr>
<td>Kale</td>
<td>50</td>
<td>3.30</td>
<td>0.70</td>
<td>27</td>
<td>13</td>
</tr>
<tr>
<td>Amaranth leaves</td>
<td>23</td>
<td>2.46</td>
<td>0.33</td>
<td>43</td>
<td>13</td>
</tr>
<tr>
<td>Spinach</td>
<td>23</td>
<td>2.86</td>
<td>0.39</td>
<td>50</td>
<td>15</td>
</tr>
<tr>
<td>Taro leaves</td>
<td>42</td>
<td>4.98</td>
<td>0.74</td>
<td>48</td>
<td>16</td>
</tr>
</tbody>
</table>

a) Source: [27]
### Table 18 Nutrient densities in selected green, leafy vegetables

<table>
<thead>
<tr>
<th></th>
<th>Vit. A ug RAE</th>
<th>Vit. B1 mg</th>
<th>Vit. B12 ug</th>
<th>Vit. C mg</th>
<th>Calcium mg</th>
<th>Iron mg</th>
<th>Zinc mg</th>
<th>Phosphorous mg</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Recommended density/1000 kcal</strong></td>
<td>960</td>
<td>0.6</td>
<td>1.0</td>
<td>75</td>
<td>600</td>
<td>9</td>
<td>13</td>
<td>600</td>
</tr>
<tr>
<td>Pumpkin leaves</td>
<td>5137</td>
<td>0.5</td>
<td>&lt;0.01</td>
<td>583</td>
<td>2066</td>
<td>117.6</td>
<td>10.6</td>
<td>5508</td>
</tr>
<tr>
<td>Kale</td>
<td>15469</td>
<td>0.2</td>
<td>&lt;0.01</td>
<td>2414</td>
<td>2716</td>
<td>34.2</td>
<td>8.9</td>
<td>1126</td>
</tr>
<tr>
<td>Amaranth leaves</td>
<td>6298</td>
<td>0.1</td>
<td>&lt;0.01</td>
<td>1868</td>
<td>9274</td>
<td>100.1</td>
<td>38.8</td>
<td>2157</td>
</tr>
<tr>
<td>Spinach</td>
<td>20230</td>
<td>0.3</td>
<td>&lt;0.01</td>
<td>1212</td>
<td>4270</td>
<td>116.9</td>
<td>22.9</td>
<td>2114</td>
</tr>
<tr>
<td>Taro leaves</td>
<td>5697</td>
<td>0.5</td>
<td>&lt;0.01</td>
<td>1229</td>
<td>2529</td>
<td>53.2</td>
<td>9.7</td>
<td>1418</td>
</tr>
</tbody>
</table>

a) Source [27]
b) Values from [4]
**Fruits**

Most fruits contain readily available energy in the form of simple sugars, mainly fructose. Those with orange or yellow coloured flesh are rich in provitamin A and others in vitamin C (Table 19 and Table 20) Fresh fruit is an excellent source of vitamin C, and should be consumed with plant based meals to enhance absorption of iron. In addition, the bioavailability of provitamin A is relatively high from fresh fruits [96]. Most children like the natural sweetness of fruits so the addition of fresh fruit to a meal may increase its perceived palatability and thus increase the intake of the whole meal. Avocado has an exceptionally high content of fat, about 15 g/100 g with about 2/3 being monounsaturated fat. The energy density is therefore high, more than 1.6 kcal/g. Therefore, if available and affordable, avocados are valuable in the diet of children with MM. Bananas is also high energy foods with an energy density around 0.9 kcal/g. Ripe bananas have high sugar content and thereby provide an easily available energy supply. Unripe bananas have high fibre content and are thus unsuitable for children with MM.

**Conclusions and recommendations on fruits**

- Most fruits are good sources of vitamin C and should be consumed raw with plant based meals to enhance iron absorption.
- Yellow and orange fleshed fruits are good sources of provitamin A
- Fruits add sweetness and colour to a meal, factors which will improve perceived palatability and often increase dietary intake among children
- The intake of fruit should be promoted as they currently have low status in many settings
Table 19 Macronutrient and energy in selected fruits. Values per 100 g raw, edible portion a)

<table>
<thead>
<tr>
<th>Fruit</th>
<th>Energy kcal</th>
<th>Protein g</th>
<th>Lipid g</th>
<th>Protein E%</th>
<th>Lipid E%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apricot</td>
<td>48</td>
<td>1.0</td>
<td>0.0</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>Avocado</td>
<td>167</td>
<td>2.0</td>
<td>15.4</td>
<td>5</td>
<td>84</td>
</tr>
<tr>
<td>Banana</td>
<td>89</td>
<td>1.1</td>
<td>0.3</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Fig</td>
<td>74</td>
<td>0.8</td>
<td>0.3</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Guava</td>
<td>68</td>
<td>2.6</td>
<td>1.0</td>
<td>15</td>
<td>13</td>
</tr>
<tr>
<td>Orange</td>
<td>47</td>
<td>0.9</td>
<td>0.1</td>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td>Mango</td>
<td>65</td>
<td>0.5</td>
<td>0.3</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Passion fruit</td>
<td>97</td>
<td>2.2</td>
<td>0.7</td>
<td>9</td>
<td>7</td>
</tr>
<tr>
<td>Pineapple</td>
<td>50</td>
<td>0.5</td>
<td>0.1</td>
<td>4</td>
<td>2</td>
</tr>
</tbody>
</table>

a) Source: [27]
<table>
<thead>
<tr>
<th>Fruit</th>
<th>Vit. A RAE (ug)</th>
<th>Vit. B1 (mg)</th>
<th>Vit. B12 (ug)</th>
<th>Vit. C (mg)</th>
<th>Calcium (mg)</th>
<th>Iron (mg)</th>
<th>Zinc (mg)</th>
<th>Phosphorous (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apricot</td>
<td>2000</td>
<td>0.63</td>
<td>&lt;0.01</td>
<td>208</td>
<td>271</td>
<td>8.1</td>
<td>4.2</td>
<td>600</td>
</tr>
<tr>
<td>Avocado</td>
<td>42</td>
<td>0.45</td>
<td>&lt;0.01</td>
<td>53</td>
<td>78</td>
<td>3.7</td>
<td>4.1</td>
<td>323</td>
</tr>
<tr>
<td>Banana</td>
<td>34</td>
<td>0.35</td>
<td>0.34</td>
<td>98</td>
<td>56</td>
<td>2.9</td>
<td>1.7</td>
<td>247</td>
</tr>
<tr>
<td>Fig</td>
<td>95</td>
<td>0.81</td>
<td>&lt;0.01</td>
<td>27</td>
<td>473</td>
<td>5.0</td>
<td>2.0</td>
<td>189</td>
</tr>
<tr>
<td>Guava</td>
<td>456</td>
<td>0.99</td>
<td>&lt;0.01</td>
<td>3357</td>
<td>265</td>
<td>3.8</td>
<td>3.4</td>
<td>588</td>
</tr>
<tr>
<td>Orange</td>
<td>234</td>
<td>1.85</td>
<td>0.85</td>
<td>1132</td>
<td>851</td>
<td>2.1</td>
<td>1.5</td>
<td>298</td>
</tr>
<tr>
<td>Mango</td>
<td>585</td>
<td>0.89</td>
<td>&lt;0.01</td>
<td>426</td>
<td>154</td>
<td>2.0</td>
<td>0.6</td>
<td>169</td>
</tr>
<tr>
<td>Passion fruit</td>
<td>660</td>
<td>0.00</td>
<td>&lt;0.01</td>
<td>309</td>
<td>124</td>
<td>17</td>
<td>1.0</td>
<td>701</td>
</tr>
<tr>
<td>Pineapple</td>
<td>60</td>
<td>1.58</td>
<td>0.40</td>
<td>956</td>
<td>260</td>
<td>5.8</td>
<td>2.4</td>
<td>160</td>
</tr>
</tbody>
</table>

Table 20 Nutrient densities in selected fresh fruits a)

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a) Source: [27]
b) Values from [4]
Algae

Algae are aquatic photosynthetic organisms which are classified into macro- and microalgae based on their size. The macroalgae consist of a group of larger aquatic plants for which the common name seaweeds is applied. The microalgae (phytoplankton, Cyanophyceae) are unicellular microscopic aquatic plants. Many species are edible. Some algae, mainly the seaweed *Porphyra* sp. (nori) and the cyanobacteria *Spirulina* sp. contain large amounts of vitamin B12 [249]. However, the majority of algal vitamin B12 appears to be widely nonbioavailable in humans [249] wherefore algae cannot be recommended as an alternative vitamin B12 source to animal source foods.

Many algal species contain essential amino acids (histidin, leucine, isoleucine and valine) wherefore they represent a potential reservoir of protein appropriate for human consumption [250]. However, the algal protein is not readily available for humans as algae are surrounded by an indigestible cellulose wall.

Seaweeds

Consumption of seaweeds is rarely seen as part of the food culture outside East Asia and its acceptance may be limited in other settings. However, several seaweeds have high contents of particularly iron, calcium and iodine [250] (Table 21). Particularly iodine and calcium are of potential nutritional importance whereas the bioavailability of iron is compromised by a high content of polyphenols.
Table 21 Mineral content of seaweeds. Values per 100 g wet weight $^{a)}$.

<table>
<thead>
<tr>
<th>Seaweed</th>
<th>Common name</th>
<th>Calcium mg</th>
<th>Iron mg</th>
<th>Iodine mg</th>
<th>Zinc mg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ascophyllum nodosum</td>
<td>Egg wrack</td>
<td>575</td>
<td>15</td>
<td>18</td>
<td>-</td>
</tr>
<tr>
<td>Laminaria digitata</td>
<td>Kombu</td>
<td>365</td>
<td>46</td>
<td>70</td>
<td>1.6</td>
</tr>
<tr>
<td>Himanthalia elongata</td>
<td>Sea spaghetti</td>
<td>30</td>
<td>5</td>
<td>11</td>
<td>1.7</td>
</tr>
<tr>
<td>Undaria pinnatifida</td>
<td>Wakame</td>
<td>112</td>
<td>4</td>
<td>4</td>
<td>0.3</td>
</tr>
<tr>
<td>Porphyra umbilicalis</td>
<td>Nori</td>
<td>34</td>
<td>5</td>
<td>1</td>
<td>0.7</td>
</tr>
<tr>
<td>Palmaria palmata</td>
<td>Dulse</td>
<td>149</td>
<td>13</td>
<td>10</td>
<td>0.3</td>
</tr>
<tr>
<td>Chondrus crispus</td>
<td>Irish moss</td>
<td>374</td>
<td>7</td>
<td>6</td>
<td>-</td>
</tr>
<tr>
<td>Ulva spp</td>
<td>Sea lettuce</td>
<td>325</td>
<td>15</td>
<td>2</td>
<td>0.9</td>
</tr>
<tr>
<td>Enteromorpha spp</td>
<td>Sea grass</td>
<td>104</td>
<td>22</td>
<td>98</td>
<td>1.2</td>
</tr>
</tbody>
</table>

$a)$ Source [250]
In addition seaweeds have a high content of soluble fibres and [250;251]. A high content of antioxidants may be an adaptation to sunlight exposure in their natural habitat.

**Microalgae**

Microalgae were once considered a source of high quality protein that might meet the protein needs of the growing world population [252]. Algal proteins are of high quality. However, the cellulose cell wall of algae presents a major constraint as it can not be digested by humans. Therefore, even microalgae need to be pre-processed resulting in high production costs, in order to make the nutrients available for human digestive enzymes [252].

Although the algae appear to represent nutritious vegetable food their use will probably be limited by their sensory characteristics (fishy taste and smell and green, brown or red colour) in populations where they are not part of the habitual diet [252]. Food preferences are conservative in many low-income countries, where protein quality of the diet is generally low. Unknown food ingredients are not easily accepted, particularly in disadvantaged populations and in crisis situations. However, in East Asia or in coastal regions where algae are accepted they should not be neglected as they can provide important nutrients.

**Spirulina**

*Spirulina* belongs to the cyanobacteria. Unlike the true microalgae, *Spirulina* does not have cellulose walls, wherefore protein and other nutrients from *Spirulina* are more bioavailable compared to yeasts and unicellular algae [253]. While the nutritional interest of other microorganisms has faded due to problems of digestibility, the cyanobacteria *Spirulina* may offer simple production of a high-quality nutritional supplement.

The protein quality of *Spirulina* is high and it is reported to be rich in highly available iron, calcium, potassium and phosphorus [254]. *Spirulina platensis* has a high content of essential n-6 polyunsaturated fatty acids, linoleic (LA, C18:2 n-6) and γ-linolenic acid (GLA, 18:3 n-6). The total lipid content is around 6% of which around 40% is PUFA [255;256]. With a total energy content of around 340 kcal/100 g, the fat contributes 16 E%.

*Spirulina* grows naturally in some alkali lakes of Africa and is possible to produce in tanks appropriate for small-scale industry. However, when produced in ponds/basins it tends to accumulate heavy metals, thus water quality is very important. The alkaline production reduces the risk of contamination or overgrowth of most other microorganisms as they can not survive the high pH caused by *Spirulina*. 
Spirulina (10 g daily) has been used in an 8 week nutritional rehabilitation study of undernourished children in Burkina Faso [257]. Improved weight gain was reported with Spirulina compared to traditional millet meals, particularly for HIV negative children. Hb also improved with Spirulina supplementation. However, the randomisation procedure was poorly described in this study. In another larger study by the same group, Spirulina and Misola (millet, soy, peanuts and sugar) were compared in a two by two factorial study on nutritional rehabilitation of severely and moderately underweight children aged 6-60 months [256]. Unfortunately, the children receiving the control diet were chosen among those families who refused to be part of the trial. However, it appeared that a combination of Spirulina and Misola was superior to each one of the supplements which were superior to the control diet (unknown composition). In conclusion the evidence is sparse, although it seems that Spirulina deserves attention as a potential natural dietary supplement for use in nutritional rehabilitation of moderately malnourished children.

Conclusions and recommendations on algae

- Seaweeds are rich in iron, calcium, iodine and a variety of antioxidants and contain several essential amino acids
- Seaweeds are traditionally used in East Asian food culture but due to its sensory characteristics it may be difficult to introduce in other food cultures
- In East Asia and in coastal regions where seaweeds are accepted they could be promoted as a nutritious component of diets for children with MM
- Microalgae may be good sources of micronutrients and high quality protein but availability might be low due to the cellulose content
- Spirulina, a cyanobacteria, seems to have protein and micronutrients with a better bioavailability, and has a high content of n-6 PUFA

Research recommendations

- Some studies suggest that Spirulina could have a role in treating children with moderate malnutrition, but this should be investigated further

Animal Source Foods

Animal products, such as meat, fish, egg and dairy products, are energy dense, excellent sources of high quality and readily digested protein and micronutrients, and contain virtually no anti-nutrients. The most important micronutrients in animal products are iron, zinc, calcium, riboflavin, and vitamin A, and B12. It has been concluded that “relatively small amounts of these foods, added to a vegetarian diet, can substantially increase nutrient adequacy” [258].
A number of studies have examined the role of animal source foods for growth, mental development, morbidity, anaemia and immune function [258-264].

The beneficial role of animal source foods (meat and milk) in the diets of 18-30 months old children was investigated in the Nutrition Collaborative Research Support Program, conducted from 1983-7 in rural areas in Egypt, Kenya, and Mexico. The estimated intakes of protein from animal sources were 13.5g/d (11.1 g/1000kcal), 3.8 (4.5), and 8.6 (8.8), respectively, corresponding to 46, 19 and 37% of the recommended protein density of 24g/1000 kcal [4]. Positive associations were found between intake of animal source foods and growth in weight and length, after controlling for socioeconomic factors [265]. Similarly, intake of animal source foods was associated with linear growth in 12-15 months old children in Peru, [266], especially in those with a low intake of complementary foods. In Mexico, consumption of foods of animal-origin was positively associated with body size at 30 months and with growth rates from 18 to 30 months in stunted children [267]. Iron, zinc, and vitamin B12 contents of animal source foods in addition to high protein quality may have contributed to these findings [261;268].

In an intervention study in Kenya, 12 schools with 544 children enrolled in class 1 were randomly assigned to meat (60-85 g/d), milk (200-250 mL/d), energy (isocaloric with the milk and meat, 240-300 mL/d), or no food supplement for a 2-year-period [264;269]. Children receiving meat had a greater increase in arm muscle area, than children in the milk and energy groups, which had a greater increase than children in the control group. The effect of milk on arm muscle area was not significantly greater than that of energy supplementation. There were no main effects of any of the supplements on linear growth. However, in children with low height-for-age Z-score at baseline, those receiving milk gained more height than children in the other groups [264]. Height gain during the intervention period was positively predicted by intakes of energy from animal source food intakes, both milk and meat [263].

Other studies, both from industrialised and from developing countries have suggested that milk has a specific stimulating effect on linear growth [270]. Observational and intervention studies from industrialized countries suggest that intake of cow’s milk stimulate IGF-I secretion, which has a direct effect on linear growth [271;272]. Equivalent amounts of protein in meat did not have an effect on IGF-I levels [272].

Many studies have shown an impact of childhood malnutrition on cognitive function, physical activity, and school attendance and performance. Positive associations have been found between intake of animal source foods and cognitive performance and verbalization in toddlers, [273;274], and school-age children getting meat had a better verbal and performance test, were more attentive to classroom work, and showed leadership behaviour [275;276].
An overview of the characteristics of animal foods that are likely to cause the beneficial effects seen after intake of animal source foods are given in Table 22.
Table 22 Characteristics of animal foods compared to plant foods to which the beneficial effects can be attributed

- Higher content of micronutrients important for growth and cognitive development (e.g. zinc, iron, and vitamin B12)
- Higher protein content and protein quality
- No anti-nutrients
- High energy density
- High fat content
- Higher content of n-3 PUFA
**Cow’s Milk**

Cow’s milk is a good source of many nutrients and has a high content of high quality protein, containing all essential amino acids. The PDCAAS is typically 120% depending on the exact amino acid distribution with tryptophan as the limiting amino acid. Mature bovine milk contains about 3.2-3.5 weight % protein, equivalent to about 20% of the energy. The main protein fractions of bovine milk are casein and whey, which account for approximately 80% and 20% of the protein, respectively. Whole cow’s milk provides a good supply of energy (266 kJ/100 g), with 45% coming from fat, while skim milk only provides 151 kJ/100 g. Cow’s milk also contains high levels of important nutrients, such as calcium, available phosphorus and magnesium and several B vitamins and bioactive factors and proteins that may have growth-promoting abilities (see the section on bioactive factors in milk). However, cow’s milk is a poor source of iron, because of a low content and poor bioavailability.

Because of its stimulating effect on linear growth milk may have an important role in prevention and treatment of stunting, especially during the first two years of life. However, it is also important in treatment of moderate wasting, as a high quality protein source with high levels of micronutrients and no antinutrients is likely to important for lean body mass accretion.

The successful treatment of severely malnourished children is based on products with either 100 % (F-100) or about 50% (RUTFs) of the protein coming from milk. Milk should also be considered a key ingredient in the foods used for treatment of children with moderate malnutrition. There is no firm evidence to determine the minimal amount of milk that would make an impact in treatment of children with MM. Based on the available data of the effects of interventions with animal foods it seems likely that a diet with 25-33% of the protein coming from milk would have a significant effect. However, there is need for studies to determine the minimal amount of milk that will have a significant effect. The amounts of milk equal to 25-33% of the recommended protein intake for children with MM (24-26 g/1000 kcal, [4]are about 200-250 ml of liquid milk or 15-20 g of milk powder or whey protein powder (DSM or whey protein concentrate (WPC) 34%) per 1000 kcal.

**Milk products**

There are many different types of cow’s milk products available, and in the following section the benefits and problems of using the different types of milk products in the treatment of children with MM will be discussed.

*Liquid milk*, i.e. either raw, pasteurised or UHT treated milk is suitable to give to children with MM. It should preferably be whole milk to provide a suitable balance between protein
and fat intake. Skim milk or milk with a reduced fat content (< 2%) should not be given, if it is not balanced with a fat intake that reaches the recommended level. Milk with reduced fat content also has a high renal solute load in relation to the energy content. A problem with pasteurised or UHT treated milk is the high price. In soured and fermented milks, a *Lactobacillus* culture converts nearly all the lactose into lactic acid and a curd is formed, e.g. yoghurt. Apart from that the nutritional content of soured milk is almost similar to the fresh milk from which it is made. Fermented milk or yoghurt has many advantages. It keeps better and the risk of growth of pathogenic bacteria is reduced. The content of lactic acid bacteria can have probiotic effects, e.g. through an influence on the gastrointestinal immune system and may reduce the risk of diarrhoea. Furthermore, the low pH will improve absorption of iron and the reduction in lactose content during fermentation will reduce effects of lactose intolerance, if present.

*Powdered milk* is often cheaper and more easily available than liquid milk. The most important problem of using powdered milk is the risk that the powder is later mixed with contaminated water when making liquid milk. Pathogens will easily multiply as milk is a good growth media, which can cause severe diarrhoea. If milk powder is used for liquid milk it should be mixed with boiled water and used within 1-2 hours to avoid contamination and bacterial proliferation. This problem of contamination is the main reason that many UN organisations (e.g. [277] and international NGOs (e.g. [278])) have a policy never to distribute powdered milk as a take-home commodity. Another reason is that liquid milk in some situations may be perceived to be an infant formula and thereby have a negative effect on breastfeeding. The most common types of powdered milk available in areas with high levels of MM are whole milk powder (WMP), which is often widely available in tins in local shops, and skimmed milk powder (SMP), which is typically only available in large quantities (e.g. bags of 25 kg) for producers of food, UN organisations and NGOs. Due to the high fat content the shelf life of WMP is limited to a year or less, depending on how it is packaged, while SMP can keep for several years if it is not fortified with vitamin A. WMP can be used for liquid milk if food safety precautions are followed. SMP should be used as an ingredient in other foods, like blended food, and should not be used for making liquid skim milk. If used for a drink without replacing the fat, the drink will be unsuited for infants and young children in the same way as skim milk. The relative content of protein and minerals, and thereby the renal solute load, will be too high if the fat is removed. This can be harmful, especially for infants and the youngest children [279].

“*Filled milk*”, which is a powdered product based on skimmed milk and vegetable oil which is sold in some low-income countries. Typically it is sold in small sachets sufficient for one glass of milk. The main advantage is that it is cheaper than whole milk powder. The exchange of
milk fat with vegetable oil could be beneficial from a nutritional point of view, depending on which vegetable oil is added.

Whey powder (13% protein) or whey protein concentrate (WPC with 34% or 80% protein) is made from the liquid part of milk that remains after casein has coagulated in cheese production. It is often not easily available locally, but can be used in programmes e.g. in the preparation of special foods or blends for malnourished children. Since it is a product left after cheese production it is typically 20-30% cheaper than dried skimmed milk per unit protein, which is an important aspect in the treatment of children with MM. Whey has a high content of both lactose and minerals. In whey powder (13% protein) the lactose content is about 70%. Whey contains many peptides and proteins with potential beneficial effects on the immune system and muscle synthesis, but this need to be confirmed in studies of children with MM [23]. Because whey is a surplus product it has been used extensively in feeding of weanling pigs. It is well documented that the growth of young weanling pigs is better on a whey based diet, compared to a diet based on cereals and legumes [23]. There are not sufficient studies to evaluate whether the effect of whey is different from the effects of DSM, as the pig studies have focused on whey because it was cheaper.

Evaporated milks are normally full-cream milks with some water removed although sometimes the milk fat is replaced with vegetable oil. Condensed milks are evaporated milks which may be made from whole milk or from milk from which the fat has been removed. They have a high concentration of sugar (about 45 per cent by weight), which reduces the relative concentration of protein and other nutrients and makes the milk unsuitable for use as a drink for infants and young children (see section on sugar). Some evaporated and condensed milk is fortified with vitamins A and D. Both types of milk are sold in tins, are expensive and should not be used as a drink. However, they can be mixed into porridge and other foods.

In hard cheeses, most of the whey is removed from the casein curd during processing. Therefore cheese has a low content of lactose and of all water soluble vitamins, as they are removed with the whey. If made from whole milk, these cheeses contain vitamin A, a little vitamin D and most of the original calcium. Cheese is expensive and therefore not a relevant food for children with MM.

Milk from other domestic animals
Most of the animal milk consumed by humans is from cattle. The second highest amount is from buffalo, which is more concentrated with higher energy, protein and fat content. Milk from many other domesticated animals is used for drinks or foods. Table 23 shows the composition of milk from domesticated animals [280]. A general pattern is that some milks are more concentrated than others with higher content of energy, protein and fat. This should be taken into account when calculating the amount to be given to children with MM. Some vitamin A and a little vitamin D is
present in all milk fats. Some milk, e.g. goat’s milk, has little or no folate compared to other milks. The concentration of iron in all milks is low and has a poor bioavailability.
Table 23 Composition of milk from domestic animals, compared to human milk

<table>
<thead>
<tr>
<th>Species</th>
<th>Energy (kcal/100 ml)</th>
<th>Protein (g/100 ml)</th>
<th>Lactose (g/100 ml)</th>
<th>Fat (g/100 ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cow (<em>Bos taurus</em>)</td>
<td>61</td>
<td>3.2</td>
<td>4.6</td>
<td>3.7</td>
</tr>
<tr>
<td>Cow (<em>Bos indicus</em>) b)</td>
<td>70</td>
<td>3.2</td>
<td>4.9</td>
<td>4.7</td>
</tr>
<tr>
<td>Yak</td>
<td>94</td>
<td>5.8</td>
<td>4.9</td>
<td>6.5</td>
</tr>
<tr>
<td>Musk Ox</td>
<td>81</td>
<td>5.3</td>
<td>4.1</td>
<td>5.4</td>
</tr>
<tr>
<td>Water Buffalo</td>
<td>88</td>
<td>4.3</td>
<td>4.9</td>
<td>6.5</td>
</tr>
<tr>
<td>Sheep</td>
<td>94</td>
<td>4.1</td>
<td>5.0</td>
<td>7.3</td>
</tr>
<tr>
<td>Goat</td>
<td>61</td>
<td>2.9</td>
<td>4.7</td>
<td>3.8</td>
</tr>
<tr>
<td>Ass</td>
<td>37</td>
<td>1.4</td>
<td>6.1</td>
<td>0.6</td>
</tr>
<tr>
<td>Horse</td>
<td>47</td>
<td>1.9</td>
<td>6.9</td>
<td>1.3</td>
</tr>
<tr>
<td>Camel</td>
<td>51</td>
<td>4.3</td>
<td>-</td>
<td>4.3</td>
</tr>
<tr>
<td>Dromedary</td>
<td>70</td>
<td>3.6</td>
<td>5.0</td>
<td>4.5</td>
</tr>
<tr>
<td>Llama</td>
<td>60</td>
<td>2.5</td>
<td>4.7</td>
<td>3.9</td>
</tr>
<tr>
<td>Human Milk</td>
<td>78</td>
<td>1.0</td>
<td>7.5</td>
<td>4.2</td>
</tr>
</tbody>
</table>

**a)** Source: [280]  
**b)** Zebu or humped cattle
Conclusions and recommendations on milk

- Liquid milk and milk powder are good sources of high quality protein and micronutrients important for growth
- The minimal amount of milk protein needed to improve growth in children with MM is not known, but a milk content providing 25-33% of the protein requirement is likely to have a positive effect on weight gain and linear growth. However, studies should be conducted to determine the amount that is cost-effective
- 200-250 ml of milk or 15-20 g of milk powder or whey protein powder (DSM or WPC34%) per 1000 kcal will provide 25-33% of the recommended protein intake (24-26 g/1000 kcal).
- Milk is likely to be more effective than meat in treating moderate stunting, as milk has a special effect on linear growth through a stimulation of IGF-I production
- Powdered milk with reduced milk fat, like DSM or whey protein, should never be used for preparing liquid milk, because of the high protein content and risk of infection if mixed with contaminated water, but can be mixed with blended foods or other foods that are cooked or heated
- Whey contains peptides and proteins that have been suggested to have positive effects, compared to DSM, but these effects have not been documented in children with MM
- The effects of using whey instead of dried skimmed milk in the treatment of children with MM should be tested in intervention trials, both because whey protein concentrate is cheaper than dried skimmed milk and because of the potential beneficial effects of whey
- Powdered whole milk should only be used as a drink for children with MM, if it is prepared under strictly controlled and hygienic conditions
- If milk is the only animal source food given, sufficient iron in the diet should be secured.
- Fermented milk products should be promoted, as they have advantages over other milk products

Research recommendations

- Research is needed to determine the amount of milk protein that has optimal cost-effectiveness in promoting growth
- Research is needed to determine if there are any advantages of using whey instead of dried skimmed milk in the treatment of children with moderate malnutrition
**Meat**

The word meat refers to skeletal muscle and related fat. Muscle tissue has a very high content of protein, about 20% in fresh and 80% in dried meat. Its protein contains all of the essential amino acids, and it is a good source of zinc, phosphorus, iron, vitamin B12, selenium, niacin, vitamin B6, and riboflavin (Table 24). Furthermore, it contains the “meat factor”, which is described in the section on bioactive factors, which enhance non-haem iron absorption. Meat contains no fibre, has negligible content of carbohydrates, and a relatively high content of fat. However, the fat content of meat can vary depending on the type of animal and how it was raised, the feed, and the part of the body. Game meat is typically leaner than farm animals and has a more favourable fatty acid composition with more n-3 fatty acids.

Meat is an expensive food, but the price varies considerably depending on local availability, whether it is cattle, sheep, goat or pig, and the cut of the meat. In some countries dried meat is available and an alternative. Meat is a very valuable ingredient in diets for children with MM. The most important quality of meat, compared to the other important animal source food, milk, is the positive effect on iron and zinc status.

**Offal**

The edible parts of animals can be divided into meat (i.e. skeletal muscle) and other (non-meat) parts, collectively called offal. The offal includes internal organs and external parts. The internal organs comprise the heart, liver, kidneys, spleen, tongue and lungs (red offal), but also brain, marrow, stomach and intestines, testicles and thymus (white offal). External parts include ears, eyes, snout, palates, tail and feet. The most important organs are liver, kidney, and intestine.

Liver is a rich source of iron and zinc, most of the B vitamins including folate, and vitamins A and D, and also has a high content of the “meat factor” (Table 24). Liver can also have a high content of contaminants. If liver is available and affordable it is highly recommended that small amounts are added to the diet of children with MM. Even if it is not possible to supply it daily, it will still be a valuable ingredient even if it is only given one to two times a month. In a study from Peru the use of liver in complementary food was an important part of an educational intervention aimed at parents to infants and young children [281]. Those randomised to the intervention had higher intakes of iron and zinc and had better weight and length gain and less stunting.

The extent to which offal is used for human consumption differs between cultures. What is considered a delicacy in one culture might be considered unacceptable in another culture. In low-income countries, better utilization of all edible parts of animals may considerably increase the
intake of important nutrients. Offal typically has a low market value and most offal has a high nutritional value. It should be considered to use acceptable and appropriate offal to a higher degree in feeding of infants and young children, especially if there is no or very low intake of animal source foods.

**Blood**

Blood from animals is used in foods in some cultures, either as an ingredient in sausages or as a drink with milk in some populations, while it is not accepted in other populations for cultural reasons. Dried blood or serum has been produced commercially as an ingredient, but has not been widely used. However, where blood or serum is culturally acceptable it can be a nutritious and cheap ingredient in food for infants and children with MM, as it is a good source of iron, vitamin B12, protein and other nutrients (Table 24). In Chile a cereal fortified with bovine haemoglobin concentrate (14 mg of iron per 100 mg of powder) seemed to reduce the risk of iron deficiency, when given to healthy breastfed infants from 4 to 12 months [282]. Among early weaned pigs, supplementation with different fractions of spray-dried plasma from pigs as well as cows improved the dietary intake and growth, and the IgG fraction was considered to be responsible for the beneficial effects [283]. In a study among 6-7 months old Guatemalan infants, those receiving a daily supplement for 8 months with a bovine serum concentrate (as a source of immunoglobulins), as compared to a whey protein concentrate, had the same growth and morbidity [284].

**Conclusions and recommendations on meat**

- The intake of meat or offal should be promoted.
- Meat is an excellent source of high quality protein and several important micronutrients and has a particular positive effect on iron status.
- Meat is expensive and in many settings not easily available and has to be prepared in a special way, e.g. minced, to be acceptable to young children.
- Liver is an exceptionally rich source of iron, zinc, vitamin A and other nutrients and should be promoted as an important part of the diet.
- The potential of increasing the use of offal and blood should be explored, where culturally acceptable, as it may be a low cost source of animal food.
Table 24 Macronutrient and energy content and nutrient densities of selected meats and other animal products. Values per 100 g

<table>
<thead>
<tr>
<th></th>
<th>Macronutrients and energy</th>
<th>Nutrient densities (per 1000 Kcal)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Energy total kcal/100 g</td>
<td>Protein g/100 g</td>
</tr>
<tr>
<td>Recommended nutrient density per 1000 Kcal a)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Beef</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Meager b)</td>
<td>126</td>
<td>21.7</td>
</tr>
<tr>
<td>Fat cutting b)</td>
<td>317</td>
<td>16.4</td>
</tr>
<tr>
<td>Blood</td>
<td>92</td>
<td>21.1</td>
</tr>
<tr>
<td>Heart</td>
<td>102</td>
<td>19.2</td>
</tr>
<tr>
<td>Liver</td>
<td>146</td>
<td>22.2</td>
</tr>
<tr>
<td>Stomach</td>
<td>97</td>
<td>16.1</td>
</tr>
<tr>
<td><strong>Pork</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Meager b)</td>
<td>107</td>
<td>22.2</td>
</tr>
<tr>
<td>Fat cutting b)</td>
<td>200</td>
<td>28.7</td>
</tr>
<tr>
<td><strong>Poultry</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chicken b)</td>
<td>167</td>
<td>31.2</td>
</tr>
<tr>
<td>Duck (meat) b)</td>
<td>119</td>
<td>18.3</td>
</tr>
<tr>
<td><strong>Others</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Goat</td>
<td>190</td>
<td>27.1</td>
</tr>
<tr>
<td>Goat blood</td>
<td>98</td>
<td>21.4</td>
</tr>
<tr>
<td>Rabbit b)</td>
<td>187</td>
<td>26.9</td>
</tr>
<tr>
<td>Mutton lean b)</td>
<td>179</td>
<td>27</td>
</tr>
</tbody>
</table>

a) Values from [4]
b) Source: [28]
Eggs

Eggs from chickens and other birds have a very high nutritional value as they provide all the nutrients necessary for a chicken embryo to develop. Eggs are often more easily available at community level than milk and meat, have a lower cost and can be bought in small quantities. More than half the energy in eggs comes from the fat in the yolk; 100g of chicken egg contains approximately 10g of fat. An average chicken egg contains about 5-6g of protein and 4-5g of high quality fat. About 20% of the fatty acids are PUFAs with a favourable n-6/n-3 fatty acid ratio of 4-5. Eggs contain a significant amount of cholesterol, about 0.5g/100g. However, this is not likely to have negative effects in infants and young children. Breast milk also contains high levels of cholesterol, which may play a role in early development. The egg white consists primarily of water and protein (13%) and contains little fat and carbohydrate. Egg protein has a very high quality with a PDCAAS of 118 %. The most important micronutrients are vitamin A, thiamine and riboflavin, and also some vitamin D. Egg contains iron, but the availability is poor, and egg white seems also to have a negative effect on absorption of non-haem iron from other foods [285]. Giving one or two eggs a day to a child with MM will be a valuable contribution to the requirements.

Conclusions and recommendations on eggs

- Eggs contain high amounts of high quality protein and fat, preformed vitamin A and other important micronutrients
- Eggs are a valuable food to give to moderately malnourished children and should be promoted

Fish

All fish are a rich source of high quality protein, and provide a range of other important nutrients, depending on species and processing. Fat content in fish species ranges from < 1 to > 30 g fat/100 g raw fish. Fatty fish are a valuable source of the long-chained n-3 PUFA. Small soft-boned fish which are eaten with bones are an excellent source of calcium and phosphorus. Furthermore, fish is a good source of zinc and bioavailable iron, and fish enhances non-haem iron absorption due to the “meat-factor” effect.

In all parts of the world, there is a general consumer preference for large sized fish. Consequently, small fish generally have a relatively low market price, and are therefore more accessible to the poor. In general, small sized fish are nutritionally superior to large fish because the edible parts of small fish include more diverse tissues such as head, bones, and the viscera, compared to large fish, where muscle tissue contributes most to the edible parts [286].
In coastal areas and in regions with rich inland water resources such as in the large river basins in Asia and Africa, (Ganges, Mekong, Nile etc) fresh fish is widely available, strongly impacted by seasonal and annual variation. In such areas, fish is often the main or only accessible animal food for poor households [287]. The fish species found in the diet in these regions reflect the biological diversity of the natural environment, and typically include a variety of small fish species. As an example, poor rural households in Bangladesh typically consume more than 50 different fish species over a year, and a single meal can include mixed batches of 5-10 different fish species [286]. Fresh fish is a highly perishable commodity, and the price is highly fluctuating following availability, market structure and the quality of the fish.

**Nutritional contribution**

The energy density in fish is determined mainly by the fat content, and ranges from 80 kcal/100 g raw fish in lean fish such as cod and other species with < 1% fat, to 360 kcal/100 g raw fish in fatty fish such as eel, which can reach more than 30% fat in raw fish [288]. In addition to interspecies variation in fat content, the specific content in fish is also influenced by the physiological condition, e.g. following reproductive cycle, and feeding conditions. For example, the fat content in Peruvian anchovy (*Engraulis ringens*) after a stress period due to the El Niño phenomenon fell from 11 % fat to less than 1% in raw fish [289].

The protein content in fish species is with few exceptions in the range of 15-25%, and most species are in the range 18-20%. The protein quality is in general high. The PDCAAS has been reported for a few species as being similar to that of meat, i.e. in the range of 70-100 %.

The fatty acid composition of freshwater fish varies between various aquatic environments (due to diet, temperature, salinity etc.) [290]. No data on the fatty acid composition of small freshwater fish species are available, but the lipid quality of the larger tropical freshwater fish is comparable to that of temperate freshwater fish [290]. Roughly estimated the PUFA content of freshwater fish is around 25% of the fat, one third of which is n-3 PUFA and half of the n-3 PUFA is long-chain PUFA.

Fish is a good dietary source of micronutrients, especially iron and zinc. A proportion of the iron ranging from 30 to 80 % is present in highly bioavailable forms, such as haem-iron or other high-molecular organic compounds, for example ferritin [291]. In general, the iron content in fish is less than in red meat and similar to the content in chicken and pork [292]. The specific iron content varies with species and with the cleaning practise determining which parts of the fish are edible [292-294]. Some small freshwater fish species of the *Esomus* genus have been identified to have 4-5 fold higher iron content (12 mg/100 g edible parts) compared to other small species from the same aquatic environment [291].
Small soft-bones fish are a good calcium source. The bioavailability of calcium from the soft-bones species *Amblyparyngodon mola* which is one of many commonly consumed small fish species in South Asia, has been shown to be similar to the bioavailability of calcium from milk [295]. The acceptability of consumption of bones is determined by the “hardness” of the bones, and “hard-boned” small fish species are therefore contributing less dietary calcium as the bones are discarded as plate waste [296]. In Table 25, calcium contribution from small fish is corrected by a “plate waste factor” to compensate the measured calcium content for bones discarded as plate waste.

Fish liver is well known as a rich source of vitamin A and D, while fish muscle tissues have low contents of these vitamins. The vitamin A content in small fish has been shown to vary with more than a factor 100 between species. In vitamin A rich species, a large proportion of the vitamin A is located in the eyes of the fish, and the traditional practices for cleaning as a determinant for edible parts are therefore a crucial parameter for the dietary contribution of vitamin A from such species [293;297]. Vitamin A in fish is present in two forms: vitamin A₁ (retinoids) and vitamin A₂ (dehydroretinoids). The biological function of vitamin A₂ is calculated as being 40% of that of vitamin A₁.

There are only a few intervention studies with fish in children. In a study in Ghana, moderately malnourished children (6-12 months) were fed a maize-based complementary diet with powdered dried fish (20% on dry weight basis) added to either a traditional maize porridge, ‘koko’ or to a complementary food ‘Weanimix’, made of 75-80% maize, 10–15% soybeans or cowpeas and 10% peanuts [298]. Other groups received either Weanimix alone or with a micronutrient supplement. The growth of the children was similar in all groups, but they all received a diet with improved protein quality. Also, powdered dried fish did not improve the iron stores of the children. In a recent study from South Africa school children were given a bread spread with fish flour from a marine source or a placebo spread [53]. Those receiving the fish spread had an improvement in verbal learning and memory.

**Processed fish**

Processing technologies to expand the shelf life of fish are drying, salting, smoking and fermentation. Icing and freezing for conservation of fish are rarely an option in low income countries and, if a cooling chain is available, there is an inherent problem of ensuring that it is intact from producer to the end-user. All processing methods of fish affect the organoleptic qualities (taste, smell, appearance) as well as the nutritional quality of the fish.

**Sun-drying**
Sun-drying of fish is widely used in Asia and Africa, and dried fish is in most cultures an accepted ingredient in mixed dishes. The organoleptic quality of traditional sun dried fish is highly variable, and caution should be exercised to identify suppliers of products of good quality. The nutritional value of dried fish is similar to that of fresh fish for protein, fat and minerals (iron, zinc and calcium), while for species with a high vitamin A content, the vitamin A is almost totally destroyed by sun-drying [297].

Small dried fish can be ground to powder and added to foods like porridge. Dried fish is available in many settings and is an affordable animal food that can be added to diets of children with MM.

*Salting*

Salting is widely used for conservation. Salted fish can be washed out before use and the original nutritional composition is largely reconstituted. The food safety of salted fish is a concern as contamination with pathogen bacteria is a risk, particularly when processed in a warm climate without cooling opportunities. Even if most of the salt is washed out, there will still be a relatively high content of salt, making salted fish an inappropriate food as salt content in the diet of malnourished children should be kept low [4].

*Fermenting*

A large number of traditional fermented fish products are known in most fish-producing regions in the world. The traditional processing is highly variable, ranging from short-term lightly-salted products with few days shelf-life, to long-term processing with a higher level of salting and with products which are preserved for several months. The nutritional value of fermented fish products is comparable with fresh fish. However, the suitability in diets for MM children has to be considered in terms of the organoleptic qualities of the products and the cultural habits for the specific local products, and in terms of food safety issues. Food safety is related to the risk of growth of pathogenic bacteria, and also in some regions especially in Asia, the risk of infections with fish-borne parasitic zoonoses such as liver flukes [299]. The risk of infections with parasitic zoonoses is eliminated by heating the fish, and therefore only relevant if a fish product is consumed raw or insufficiently heated. Raw, fermented fish may contain thiaminase which can reduce thiamin pyrophosphate effect. Thiaminase is destroyed by heating [300].

*Tinned fish*

Tinned fish is a convenient substitute for fresh fish. Fat fish like tuna and mackerel are energy dense, especially when preserved in oil. The nutritional profile of tinned fish is largely similar to
fresh fish, but the lipid profile can change slightly in the tinning process [301] and after 3-6 months of storage [302]. Tinned fish cannot be stored after opening due to risk of bacteria contamination [303].

Fish protein concentrate

Fish protein concentrate (FPC) is a powdered product made from whole fish, with a high protein concentration. However, FPC is not well adapted for human consumption because the taste and smell is unacceptable even in refined products. Decades ago, FPC was considered for use as a protein supplement for malnourished children. In one early study, FPC was compared with skimmed milk for the ability to induce weight gain and rehabilitation in children suffering from kwashiorkor [304]. It was concluded that FPC had an impact largely comparable to that of skim milk powder, but the FPC diet was not well accepted by the majority of the children. In a similar study in measles infected children, the tolerance of the FPC diet was reported to be acceptable, and the nutritional value comparable to milk powder [305]. However, at present, there are no practical applications of FPC in feeding MM children due to the organoleptic qualities.

Contamination

The accumulation of mercury in fatty fish is a potential health risk. Some high-income countries have issued guidelines for restricted intake of fatty fish by pregnant women and children, to avoid toxic exposure to toxic substances such as mercury. Accumulation of polychlorinated biphenyls (PCBs), lead, arsenic and cadmium in fish stocks may pose a health hazard. Fish originating from polluted environments may be safe for consumption as especially lean fish with a short life-cycle are less likely to accumulate contaminants. The contamination risks are mainly in carnivore fatty fish with long life-cycles such as tuna, and for feeding MM children the caution should be exercised to avoid high and frequent intake of for example tinned tuna or mackerel, unless the product is known to have a low level of contamination. Many small, freshwater and coastal fish are lean with short life cycles, preventing accumulation of most potential contaminants.

The use of pesticides in agricultural production may be hazardous to fish living in rice fields. It is usually not a major problem in other settings. Caution should be exercised to the use of toxic substances in local post-harvest conservation, such as the use of DDT to prevent insect infestation during sun drying of fish or the use of diluted formalin for conservation of 'fresh' fish. These contamination risks should be avoided by using trustworthy suppliers.

Conclusions and recommendations on fish

- Fish is a good source of high quality protein and micronutrients
• Small fish, which are consumed whole are an especially good source of highly bioavailable calcium, iron, zinc and vitamin A.

• Vitamin A is not preserved in sun-dried fish

• Fillets from large fish are low to moderate sources of iron and zinc

• Fish enhances absorption of non-haem iron. The enhancing effect is about half that of meat

• Fish is beneficial to add to the diet as an animal source food, replacing meat. The nutritional impact of adding small amounts (10-50g) of fish to a meal remains to be documented.

• The issues of food safety and contamination should be considered if fish are used in diets of children with MM
Table 25 Macronutrient and energy content and nutrient densities in freshwater and marine fish species. Values per 100 g raw fish.

<table>
<thead>
<tr>
<th>Energy and macronutrients</th>
<th>Nutrient densities per 1000 Kcal</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Energy</td>
</tr>
<tr>
<td></td>
<td>Kcal E%</td>
</tr>
<tr>
<td>Recommended nutrient density (^{c)})</td>
<td></td>
</tr>
<tr>
<td><strong>Marine species (^{d)})</strong></td>
<td></td>
</tr>
<tr>
<td>Herring (Clupea harengus)</td>
<td>201</td>
</tr>
<tr>
<td>Saithe/Pollock (Pollachius virens)</td>
<td>81</td>
</tr>
<tr>
<td>Haddock (Melanogrammus aeglefinus)</td>
<td>85</td>
</tr>
<tr>
<td><strong>Small freshwater species (^{e)})</strong></td>
<td></td>
</tr>
<tr>
<td>Mola (Amblypharyngodon mola)</td>
<td>112</td>
</tr>
<tr>
<td>Darkina (Esomus danricus)</td>
<td>113</td>
</tr>
<tr>
<td>Puti (Puntius sophore)</td>
<td>135</td>
</tr>
<tr>
<td><strong>Cultured freshwater species (^{f)})</strong></td>
<td></td>
</tr>
<tr>
<td>Rui (Labeo rohita)</td>
<td>111</td>
</tr>
<tr>
<td>Silver carp (Hypophthalmichthys molitrix)</td>
<td>112</td>
</tr>
<tr>
<td>Cyprinus carpio (common carp)</td>
<td>123</td>
</tr>
<tr>
<td>Oreochromis niloticus (tilapia)</td>
<td>89</td>
</tr>
</tbody>
</table>

\(^{a)}\) Vitamin A contents in fish species are calculated as retinol activity equivalents (RAE) from contents of retinoids (vitamin A\(_1\)) and dehydroretinoids (vitamin A\(_2\)) [297].

\(^{b)}\) Corrected according to [296]

\(^{c)}\) Values from [4]

\(^{d)}\) Source: [27]

\(^{e)}\) Values from [286] and unpublished data, unless otherwise noted

\(^{f)}\) Values from [306]

\(^{g)}\) Carp in Beysehir Lake in Turkey contain from 29 to 43 % PUFA depending on time of the year [307]

\(^{h)}\) Tilapia from the Nile contains 20% PUFA [308], while Tilapia from Lake Chamo in Ethiopia contained around 26% PUFA [290]
Other Animal Source Foods

Lack of animal-source foods in the diet of people in low-income populations contributes to undernutrition and especially the widespread deficiencies of iron, zinc and vitamin A. Conventional animal source foods (i.e. meat and organs from cows, goat, sheep, pigs, poultry, eggs and fish) are often inaccessible or unaffordable.

Other animal source foods with high content and bioavailability of important micronutrients may be readily available, affordable, yet under-utilized. Some of these foods cannot be promoted, as they may be culturally unacceptable or at risk of extinction. Foods that could be promoted include low-valued parts of domestic animals, as well as snakes, rodents, frogs, snails and insects, from fields, or uncultivated land and forest, and from aquatic environments.

For example, insects have constituted a fundamental part of the diet among previous and contemporary hunter-gatherers [309]. While entomophagy (i.e. insect-eating) declined with the uptake of agriculture in most regions, and has been reinforced by modern prejudice against insects, it has remained part of traditional knowledge among subsistence farmers [310]. As such, insects are still occasionally collected and eaten, especially in times of drought when the modern crops fail. For example, more than 65 species of insects have been reported as food in the Democratic Republic of Congo [310].

The nutritional importance of entomophagy has not been fully appreciated, since focus has been on protein content. However, the very high content of important micronutrients, in particular iron and zinc, in insects, may be of considerably greater importance. The bioavailability of iron and zinc in the insects, and whether insects may have the “meat factor” effects remains to be studied. A survey among elderly Luo in western Kenya identified five commonly eaten insect species, including ant, termites and crickets [311]. The iron and zinc content were up to 1562 mg and 341 mg per 100 g dry matter, respectively. Although most insects are only available in short periods in specific seasons, they can be dried and kept for later use. In South Africa, it has been estimated that 16,000 tonnes of dried mopane caterpillars are sold each year.

As such, even relatively small amounts of insects may contribute considerably to the intake of protein and important micronutrients, in complementary diets, and in diets for malnourished children, including those with HIV infection, where a high nutrient density is required.

Conclusions and recommendations on “Other Animal Source Foods”
• Snakes, rodents, frogs, snails and insects may in some settings constitute an important and under-utilized resource
• Insects may have a very high content of protein, as well as minerals such as iron and zinc
• Small amounts of these other animal source foods can provide an important contribution to the diets of children with MM, if cultural acceptable

Oils and fats

Vegetable oils and fats are important ingredients in the diet of children with MM. They are expensive ingredients and often the intake is low in populations with high rates of malnutrition. Apart from being low in fat the basic diet of malnourished children appears to be specifically low in n-3 PUFA, whereas many of the oils and staple foods supply some n-6 PUFA (Table 12, Table 15 and Table 26). These aspects are discussed in the section on fat content and dietary fatty acid composition, which also includes the recommendations for intake of n-6 and n-3 PUFA for moderately malnourished children (5g n-6 and 0.55g n-3 PUFA/1000 kcal). In this section the characteristics and the role of oils and fats in diets for moderately malnourished children are discussed.

The potential health effects of an optimal intake of PUFA and the large variation in PUFA content of different vegetable oils make the source of vegetable oil used in foods for MM children important. Food declarations often do not mention the kind of vegetable oil that is used. This is not satisfactory. The source and amount of fat should be declared in processed foods used for children with MM.

Some of the oils that are frequently used in low-income countries, such as palm oil and coconut oil, have a high content of saturated fatty acids. These fatty acids provide a good source of energy, but do not provide essential fatty acids. The potential negative effect of a high intake of saturated fat, which is a concern in high-income countries, is not likely to be a problem in the treatment of malnourished children. Palm oil is characterised by a high content of palmitic acid, about 45% and has a very low content of n-3 PUFA and thus a high n-6/n-3 PUFA ratio of about 45. Unheated palm oil is red, due to a high content of beta-carotene. Palm kernel oil, which is made from the fruit seeds and not the palm fruit like palm oil, has a very different fatty acid composition. Like in coconut oil, more than 80% of the fatty acids in palm kernel oil are saturated fatty acids of which most are the medium chained fatty acids, lauric and myristic acid and only about 8 % is palmitic acid. Compared to red palm oil the palm kernel oil and coconut oil have a much lower content of oleic acid and PUFA.
Most other common vegetable oils have a high content of either oleic acid (18:1n-9), linoleic acid (LA; 18:2n-6) or both (Table 26). Oleic acid acts as a competitor in the metabolic processing of the essential fatty acids, LA and α-linolenic acid (ALA, 18:3n-3), and can as such to some extent possibly spare the essential fatty acids for their essential functions [312]. The oleic acid-rich oils may thus be a good choice to use with other more essential fatty acid rich oils. Only few of the common vegetable oils contain a significant amount of ALA; the most common is soybean oil, but canola/rapeseed oil, walnut oil and flaxseed oil also contain significant amounts. However, none of these vegetable oils contain long-chain n-3 PUFA (EPA and DHA), which is only supplied in large quantities from marine foods. The n-3 PUFA-containing oils may be the best choice for malnourished children. The needs for n-3 PUFA could be fulfilled either by giving soybean oil as the main fat source or by supplying some flaxseed oil in combination with a vegetable oil that is available and affordable. To supply the 0.55g of n-3 PUFA needed per 1000 kcal 5 ml of rapeseed oil or 8 ml of soybean oil is needed per 1000 kcal. To cover the requirements of n-3 PUFA with other vegetable oils with lower n-3 PUFA content is not realistic. For corn oil it would take 70 ml oil per 1000 kcal, and the recommended n-6/n-3 ratio will never be reached when large quantities of corn oil is used.

Soybean oil is of high quality as it contains a high proportion of unsaturated fatty acids; the major unsaturated fatty acids being LA, ALA, and oleic acid (18:1n-9). Soybean oil contains a high amount of n-6 PUFA, less n-3 PUFA, but compared to other oils a relatively high content of n-3 PUFA (100 g of soybean oil contain 7 g ALA and 51 g of LA) resulting in an n-6/n-3 PUFA-ratio of 7, close to the recommended ratio of 6 [4]. In comparison, flaxseed oil, also called linseed oil, has a very high n-3 PUFA (ALA) content and thereby a n-6/n-3 PUFA-ratio of 0.2. The n-3 PUFA content of rapeseed oil (canola oil) is in between the two with respect to the ratio between n-3 PUFA and n-6 PUFA; it has a high content of oleic acid and is used increasingly as the main vegetable oil in many European countries. Corn oil, sunflower oil, grape seed oil and peanut oil are unbalanced sources of essential fatty acids, with high amounts of n-6 fatty acids and only little n-3 PUFA. Using these oils will make the essential fatty acid intake more unbalanced.

Rapeseed oil may have high levels of erucic acid, which may have negative health effects, but some types of rapeseed oil, like canola oil, have low levels of erucic acid. In the EU directive for composition of infant formula it is stated, that the amount of erucic acid should not be above 1% of the total fat content. It therefore seems reasonable to adopt the same limit for infants and children with MM. Flaxseed oil has traditionally been used for wood finish but is now becoming a more common food supplement sold in health shops. It is rapidly oxidised, and may produce toxic oxidation products, if antioxidants are not added. Although flaxseed oil is a rich
source of n-3 PUFA, it should not be used for infants and young children before potential negative effects have been examined further.

Palm oil, soybean oil and rapeseed oil are among the oils produced in the largest amounts globally. There are only moderate differences in price among the three types of vegetable oil used commonly by World Food Programme: soybean oil, palm oil and sunflower oil. Based on prices from January 2009 the cheapest oil was palm oil (about 800 US$ per ton) with soybean oil and sunflower oil being about 20% more expensive and rapeseed oil about 30% more expensive. To cover the PUFA requirements soybean oil or rapeseed oil which at present is only about 10% more expensive, are the best choices.

Vegetable oils can be hydrogenated to produce a solid or a semi-solid fat, which can have technical advantages in food production, like in baking. When a vegetable oil is hydrogenated the unsaturated fat is transformed into saturated fat, which increases the melting point of the fat. If the vegetable oil is only partially hydrogenated trans fatty acids are produced which seems to have several adverse health effects, especially on cardiovascular risk factors and may counteract the effects of cis-unsaturated fatty acids [313]. Partially hydrogenated fat is not allowed in the Codex Alimentarius standard for cereal based infant foods [314]. Thus, partially hydrogenated vegetable oils should not be used in diets for children with MM.

The most common animal fats include butter, ghee, lard and fish oil. Ghee is boiled clarified butter without the protein from the butter and lard is pure fat from the pig. Lard has considerably more n-3 PUFA than butter (Table 26) and both lard and butter have n-6 to n-3 ratios of 9-10, which is within the recommended range. However, it is not realistic to cover the requirements of PUFA through these fat sources, as too large amounts would be needed. Fish oil has a very high content of n-3 PUFA, about 35%. In order to cover the recommended intake of n-3 PUFA only about 1.5 ml of fish oil is needed per 1000 kcal. As fish oil contains n-3 PUFA in its long-chained form, DHA and EPA, this amount is likely to be more effective than equivalent doses of n-3 PUFA with only ALA.
Table 26 Fatty acid composition of common edible oils. Values in g/100g

<table>
<thead>
<tr>
<th>Fatty acids b)</th>
<th>SFA</th>
<th>MUFA</th>
<th>PUFA</th>
<th>n-6 PUFA</th>
<th>n-3 PUFA</th>
<th>n-6/n-3</th>
<th>Dominant FA (&gt;10%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vegetable oils</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coconut Oil</td>
<td>86.5</td>
<td>5.8</td>
<td>1.8</td>
<td>1.8</td>
<td>0.0</td>
<td></td>
<td>12:0 &amp; 14:0</td>
</tr>
<tr>
<td>Palm Oil</td>
<td>49.3</td>
<td>37.0</td>
<td>9.3</td>
<td>9.1</td>
<td>0.2</td>
<td>45.5</td>
<td>16:0 &amp; 18:1</td>
</tr>
<tr>
<td>Olive Oil</td>
<td>13.8</td>
<td>73.0</td>
<td>10.5</td>
<td>9.8</td>
<td>0.8</td>
<td>12.8</td>
<td>18:1</td>
</tr>
<tr>
<td>Sunflower Oil, high oleic</td>
<td>9.7</td>
<td>83.6</td>
<td>3.8</td>
<td>3.6</td>
<td>0.2</td>
<td>18.8</td>
<td>18:1</td>
</tr>
<tr>
<td>Sunflower Oil (LA &lt;60%)</td>
<td>10.1</td>
<td>45.4</td>
<td>40.1</td>
<td>39.8</td>
<td>0.2</td>
<td>199</td>
<td>18:1 &amp; 18:2</td>
</tr>
<tr>
<td>Sunflower Oil (LA app. 65%)</td>
<td>10.3</td>
<td>19.5</td>
<td>65.7</td>
<td>65.7</td>
<td>0.0</td>
<td></td>
<td>18:2 &amp; 18:1</td>
</tr>
<tr>
<td>Groundnut/Peanut Oil</td>
<td>16.9</td>
<td>46.2</td>
<td>32.0</td>
<td>32.0</td>
<td>0.0</td>
<td></td>
<td>18:1 &amp; 18:2</td>
</tr>
<tr>
<td>Grape seed Oil</td>
<td>9.6</td>
<td>16.1</td>
<td>69.9</td>
<td>69.6</td>
<td>0.1</td>
<td>696</td>
<td>18:2 &amp; 18:1</td>
</tr>
<tr>
<td>Sesame Oil</td>
<td>14.2</td>
<td>39.7</td>
<td>41.3</td>
<td>41.3</td>
<td>0.3</td>
<td>138</td>
<td>18:2 &amp; 18:1</td>
</tr>
<tr>
<td>Maize/Corn Oil</td>
<td>13.0</td>
<td>27.6</td>
<td>54.7</td>
<td>53.2</td>
<td>1.2</td>
<td>45.8</td>
<td>18:2, 18:1 &amp; 16:0</td>
</tr>
<tr>
<td>Soybean Oil</td>
<td>15.7</td>
<td>22.8</td>
<td>57.7</td>
<td>50.4</td>
<td>6.8</td>
<td>7.4</td>
<td>18:2, 18:1 &amp; 16:0</td>
</tr>
<tr>
<td>Canola/Rapeseed Oil</td>
<td>6.4</td>
<td>55.4</td>
<td>33.2</td>
<td>22.1</td>
<td>11.1</td>
<td>1.9</td>
<td>18:1 &amp; 18:2</td>
</tr>
<tr>
<td>Flaxseed Oil</td>
<td>9.4</td>
<td>20.2</td>
<td>66.1</td>
<td>12.7</td>
<td>53.3</td>
<td>0.2</td>
<td>18:3, 18:1 &amp; 18:2</td>
</tr>
<tr>
<td><strong>Animal fat</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Butter, salted</td>
<td>51.4</td>
<td>21.0</td>
<td>3.0</td>
<td>2.7</td>
<td>0.3</td>
<td>8.8</td>
<td>14:0, 16:0, 18:0 &amp; 18:1</td>
</tr>
<tr>
<td>Lard</td>
<td>39.2</td>
<td>45.1</td>
<td>11.2</td>
<td>10.2</td>
<td>1.0</td>
<td>10.2</td>
<td>16:1, 16:0 &amp; 18:0</td>
</tr>
<tr>
<td>Fish oil</td>
<td>29.1</td>
<td>23.7</td>
<td>42.3</td>
<td>3.6</td>
<td>38.7</td>
<td>0.09</td>
<td>22:5n-3, 16:0 &amp; 22:6n-3</td>
</tr>
</tbody>
</table>

a) Sources: [27;315]
b) SFA: Saturated fatty acids; MUFA: Monounsaturated fatty acids; PUFA: Polyunsaturated fatty acids; LA: Linoleic acid (18:2n-6); FA: Fatty acid given as number of carbon atoms in chain: number of double bonds
Conclusions and recommendations on oils and fats

- Vegetable oils are important ingredients in diets for malnourished children as they supply both energy and essential fatty acids.
- Soybean and rapeseed oil are the oils that best covers the requirements of PUFAs at a reasonable cost.
- Adding about 15 ml (a tablespoon) of soybean oil daily to the diet of a malnourished child will cover the requirements of essential fatty acids and will supply about 10% of the energy requirements.
- If vegetable oils with low content of n-3 PUFA are used the n-3 PUFA requirements could be covered by adding small amounts of fish oil.
- The source of vegetable oil used in processed food for MM children should be declared.
- Partially hydrogenated vegetable oils should not be used in diets for children with MM, because of potential adverse effects of trans fatty acids.

Research recommendations

- The effects of an optimal n-3 fatty acid intake in children with moderate malnutrition should be studied.

Sugar

Sugar only contributes energy and no other nutrients like vitamins or minerals. Brown sugar, which typically is a mix of white sugar and molasses, contain some iron and calcium. Molasses contains 4.7 mg iron and 205 mg calcium per 100 g[27], but constitutes only about 5% of brown sugar and is not available at a reasonable price. The energy content of sugar is a little less than half the content of fat. Still, added sugars have a relatively high energy density compared to many other foods as the water content of sugar is zero. By adding sugar to foods the energy density increases, but at the same time, the nutrient density of the food will decrease and the osmolarity will increase. The higher energy density is likely to have a positive influence on energy intake, an effect that is worrying in high-income societies with a growing prevalence of obesity. In treatment of children with wasting who have an increased energy need, this is positive. However, if high sugar content is used in diets for children with moderate stunting who need treatment over a long period, this may impose a risk of overweight. Another important aspect of added sugar is how it affects taste. The
sweet taste is likely to improve palatability and thereby the acceptability of the food. Adding sugar may therefore help to increase energy intake both through increased energy density and through an improved taste, an effect that may be especially important in situations with bulky foods and poor appetite. However, when used for a longer period of time, there is a risk of reinforcing a preference for sweet foods and hence too high energy intake, also later in life.

Adding sugar to a food or a diet reduces the nutrient density, as it provides no vitamins and minerals. Studies from high-income countries have shown that a high sugar intake, above 15 energy percent has a negative influence on certain important nutrients, like zinc where the nutrient density (mg/10 MJ) was below the recommended level [316;317]. In 2003 Report of a Joint WHO/FAO Expert consultation on Diet, Nutrition and Prevention of Chronic Diseases [318] recommended that added sugar intake should not go above 10 energy percent at the population level. There are no firm scientific data to support the level of 10 energy percent, but rather it has been chosen as a prudent level. In treating children with moderate malnutrition 10 energy percent seems to be a reasonable maximum level. If more than 10 energy percent is added to a food or diet, there is a need to secure that the content of vitamins and minerals is sufficient. In treatment of moderate wasting for a limited period, a higher content than the 10 energy percent, but not more than 20 energy percent, may be acceptable. Sugar adds considerably to the osmolarity of the food which should also be taken into consideration.

A high and frequent intake of sugar over long time may increase the risk of caries especially in situations with poor oral hygiene [318]. However, this may not be important during shorter periods of rehabilitation. Giving a diet with a high sugar content over a long period may also result in difficulties for the child afterwards to accept a diet with no or a very low sugar content. This problem, which has been observed after treatment of severe malnutrition, should be investigated further.

**Conclusions and recommendations on sugar**

- Adding sugar increases energy intake through increased energy density and improved taste, but reduces the nutrient density of the food
- Adding sugar may increase the risk of caries
- The amount of sugar should generally not exceed 10 energy percent, although 20 energy percent for up to a few weeks may be acceptable for treatment of wasted children

**Research recommendations**

- It should be investigated if children after a treatment period with a high sugar intake have difficulties accepting a normal diet with no or very little sugar
Salt

Malnourished children have only a low requirement of sodium as they are in a sodium retaining state [4]. If the sodium intake is high it will increase the renal solute load which might result in hypernatriemic dehydration. Furthermore, a high sodium intake may result in heart failure. Sodium adds taste to a meal, but this is not likely to be important for infants and young children. Thus there is no need to add salt (sodium chloride) to the diet of an infant or child with moderate malnutrition. Salt is used as a vehicle for iodine fortification, but children should have their iodine requirement covered in another way.

Conclusions and recommendations on salt intake

- Salt (sodium chloride) should not be added to the diet of children with MM.

Other issues

Appetite

There are some studies suggesting that different foods have different effects on appetite, apart from the effect of the energy content. This is an area that has been studied in detail in relation to obesity but also an area that is relevant for malnutrition [22]. To our knowledge, there is not much information available in relation to treatment of malnutrition, although this is an area with potentially high importance. Some studies suggest that a high protein content in a diet will have a negative effect on energy intake [22] which could be an important reason, apart from cost, not to have a too high protein content in diets for malnourished children. It has also been suggested that beans can have a negative effect on appetite, which may be caused by colonic fermentation of oligosaccharides producing discomfort because of gas production and slowing gut transit time [319]. This could be another reason for not using or only using small amounts of beans and legumes in diets for children with MM. Other foods have been suggested to influence appetite less than would have been expected from the energy content. Some studies have shown that liquid sugar, as in soft drinks, and especially fructose glucose syrup, has a limited effect on appetite, and may therefore result in increased energy intake and weight gain [320;321]. However, liquid sugar is not suitable for long term use for MM children.
Conclusions and recommendations on appetite

- Some foods have an influence on appetite (positive or negative) beyond the effect of the energy content
- Research is needed to assess the effects of different foods, ingredients, nutrients and dietary diversity on appetite among malnourished children

Cost

The cost of foods used for treating children with MM is an important aspect to consider. Especially the differences in price between animal and non-animal foods are considerable and need to be taken into consideration when deciding which foods to recommend. In balancing the price against the effect, it should be considered that treating moderate malnutrition is likely to have a very important impact on health, by preventing the development of severe malnutrition, by reducing morbidity and mortality and by improving mental and physical development. In this balance it should also be taken into account that the foods used for treating severe malnutrition are based on milk with 100% milk protein in F-100 and 50% milk protein in RUTFs. Another important aspect is how much animal source food is needed to make an impact. Here it is proposed that if 25-33% of the protein comes from animal food sources it can make an impact on growth. However, there is a need for more research to establish the minimal amount of animal source food that makes a difference.

It is difficult to obtain comparable prices, as prices differ considerably with location, transport needed, subsidies, market situation and season. A very rough estimate is that animal foods are 5-10 times more expensive than a basic staple and that CSB and blended infant food is 2-3 times as expensive as a basic staple food (Pieter Dijkhuizen, personal communication). In Table 27 we have given some examples of world market wholesale prices of different foods and commodities provided by WFP and have for each food calculated the price for energy (1000 kcal) and for protein (24 g, which is the protein requirement per 1000 kcal for children with MM [4]). Prices for both August 2008 and for January 2009 are given, showing the dramatic fluctuations over a short period. The figures give a rough idea of the relative differences between relevant commodities and especially the difference between animal source foods and other foods, bearing in mind that the difference between retail market prices and wholesale process can be larger for animal source foods. Cereals are the cheapest sources of energy, with maize the cheapest. Oils are about double the price while soy beans and legumes are at a higher level and animal foods much higher. The cheapest sources of protein are soy beans, wheat and maize. Interestingly, protein from rice is at the same level as chickpeas and green lentils and about half the price of one of the cheapest animal
source proteins SMP. In estimating the cost of diets for children with MM it is possible to take the requirements of all macro- and micronutrient into consideration using linear programming [322].
Table 27 Crude prices for energy (1000 kcal) and protein (24g) for selected commodities a)

<table>
<thead>
<tr>
<th>Commodity</th>
<th>Price US$/Mt</th>
<th>Price US$/Mt</th>
<th>Energy content c) (kcal/100 g)</th>
<th>Protein content c) (g/100g)</th>
<th>Price - Energy (US$/1000 kcal) Jan 2009</th>
<th>Price - Protein (US$/24 g) Jan 2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>340</td>
<td>225</td>
<td>330</td>
<td>12</td>
<td>0.07</td>
<td>0.05</td>
</tr>
<tr>
<td>Maize</td>
<td>240</td>
<td>190</td>
<td>360</td>
<td>9</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>Rice</td>
<td>490</td>
<td>340</td>
<td>360</td>
<td>8</td>
<td>0.09</td>
<td>0.10</td>
</tr>
<tr>
<td>Corn Soy Blend</td>
<td>530</td>
<td>430</td>
<td>380</td>
<td>18</td>
<td>0.11</td>
<td>0.06</td>
</tr>
<tr>
<td>Soybeans</td>
<td>800</td>
<td>620</td>
<td>445</td>
<td>37</td>
<td>0.14</td>
<td>0.04</td>
</tr>
<tr>
<td>Chickpeas</td>
<td>925</td>
<td>775</td>
<td>364</td>
<td>19</td>
<td>0.21</td>
<td>0.10</td>
</tr>
<tr>
<td>Whole green lentils</td>
<td>1000</td>
<td>825</td>
<td>352</td>
<td>26</td>
<td>0.23</td>
<td>0.08</td>
</tr>
<tr>
<td>Skimmed Milk Powder</td>
<td>3800</td>
<td>3120</td>
<td>360</td>
<td>36</td>
<td>0.87</td>
<td>0.21</td>
</tr>
<tr>
<td>Dried Whole Milk</td>
<td>4250</td>
<td>4250</td>
<td>500</td>
<td>25</td>
<td>0.85</td>
<td>0.41</td>
</tr>
<tr>
<td>Beef b)</td>
<td>4200</td>
<td>3200</td>
<td>150</td>
<td>29</td>
<td>2.13</td>
<td>0.26</td>
</tr>
<tr>
<td>Soybean oil</td>
<td>1875</td>
<td>1150</td>
<td>880</td>
<td>0</td>
<td>0.13</td>
<td>N/A</td>
</tr>
<tr>
<td>Sunflower oil</td>
<td>2250</td>
<td>1150</td>
<td>880</td>
<td>0</td>
<td>0.13</td>
<td>N/A</td>
</tr>
<tr>
<td>Sugar</td>
<td>440</td>
<td>430</td>
<td>390</td>
<td>0</td>
<td>0.11</td>
<td>N/A</td>
</tr>
</tbody>
</table>

a) Prices are the median of the different prices given within each commodity from the WFP FOB price lists from July-August 2008.
b) Beef price from FAO International Commodity Price list, Argentina August and November 2008 cif prices.
c) Energy and protein content from the tables in this review or from USDA food table.
Conclusions and recommendations on prices

- Treating children with moderate malnutrition is important to prevent the development of severe acute malnutrition and severe stunting, which should be taken into consideration when evaluating the cost of the foods and ingredients used.
- An important aspect of the cost of the treatment is determining through intervention studies the amount of animal protein needed to make an impact on recovery.

Overall conclusions

It is not difficult to design an optimal diet for children with moderate malnutrition if the resources are available. The diet used for the treatment of severe malnutrition with a high content of animal food, i.e. milk powder, and a low content of fibres and antinutrients will be effective also in treatment of moderate malnutrition. However, the ingredients in such a diet are expensive, not available in most settings and not appropriate for a low cost sustainable home based treatment.

A main issue is to identify a cost-effective balance between the amount of animal foods, with a high content of minerals important for growth, e.g. phosphate and zinc, a high content of protein with a high quality (PDCAAS), with virtually no antinutrients, but also with a high cost, and the amount of plant based foods. This balance is especially important if the plant based foods are unrefined cereals and legumes, with a high content of fibres and antinutrients.

Infants and young children are more susceptible to the negative effects of antinutrients such as phytate and fibres, especially insoluble fibres, than older children. This is particularly crucial for malnourished children who often have a compromised and thereby more vulnerable gastrointestinal tract.

The most used animal source foods are milk, meat and eggs. However there are several other types of animal food sources which are often cheaper and can be valuable ingredients in the diet of moderately malnourished children if they are culturally acceptable. These include, fish, especially small fish which are eaten whole and therefore have a high nutrient content, and other animal source foods such as insects, snakes and rodents. Offal may also be an under-utilised animal source food. Milk seems to have a special effect in stimulating linear growth through an increased production of IGF-I.

When cereals and legumes constitute a large part of the diet it is important that the content of antinutrients and fibres are reduced through food processing. Soaking, malting and fermentation reduce the content of antinutrients. Milling also reduces the content of antinutrients, but as the content of both nutrients and antinutritional factors are high in the outer layer of grains, extensive milling will also reduce the nutrient density.
The fat content, and thereby the energy density is typically low in a traditionally plant based diet and increasing the content of fat is a well known and efficient way to increase nutrient density. To obtain an adequate energy density the fat energy percentage should be at least 30, and preferably, especially for wasted children, between 35 and 45 energy percent. An issue that needs attention is the fat quality in the diets of children with MM. The intake of PUFA, especially n-3 fatty acids is low in these plant based diets, and also in many oils. Several of the symptoms seen in children with MM could be caused by PUFA deficiency. Diets for moderately malnourished children should contain at least 4.5 energy percent of n-6 PUFA and 0.5 energy percent of n-3 PUFA. Soybean, rapeseed oil and fish have high contents of n-3 fatty acid.

Research recommendations
There are still many unresolved aspects of the dietary treatment of children with MM that needs to be investigated further, as highlighted in the sections with conclusions and recommendations in this review. Among the most important is a need to identify the minimum quantity of different animal source foods needed to support growth and development of children with MM. Furthermore, there is a need to identify appropriate and cost-effective methods for reducing the content of anti-nutrients and fibres in plant based foods. The question of the effect of fat quality for growth and cognitive development in children with MM also needs investigation.

When evaluating which foods are effective in treating moderate malnutrition weight gain has been the traditional outcome. However, more appropriate outcomes to assess healthy physical development should be included, such as increase in lean body mass and linear growth velocity and functional outcomes such as physical activity and psychomotor development.

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