Cow’s Milk in Treatment of Moderate and Severe Undernutrition in Low-Income Countries

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Abstract

Cow’s milk products have a central role in treatment of undernutrition, and the introduction of products with a high milk content (F-100 and ready to use therapeutic foods) has resulted in marked improvements in weight gain and reduction in mortality. Milk also has a specific effect on linear growth. Milk protein has a high quality score (PDCAAS) and contains many peptides and other bioactive factors, which might have special effects on recovery from undernutrition. Milk is an important source of minerals supporting growth (type II nutrients), such as potassium, magnesium, phosphorus and zinc, and the high lactose content also seems to support growth due to a prebiotic effect and improved absorption of minerals. The risk that the use of cow’s milk products suppresses breastfeeding should be prevented by supporting mothers in breastfeeding. There is consensus that children with severe undernutrition should be treated with products with high milk content, but because of the high cost of milk there is a need to perform more studies to determine the minimal amount of milk protein needed to make a clinically relevant difference in treating the 36 million children with moderate wasting. Such studies should not only focus on weight gain but also on linear growth, body composition, physical activity and cognitive development.

Introduction

Cow’s milk products have a central role in treatment of undernutrition both in industrialized and developing countries. In industrialized countries, almost all products used for enteral feeding of malnourished patients in a hospital
setting, for both children and adults, are based on cow’s milk. Also, successful treatment of severe undernutrition in most developing country settings is based on products where protein comes from cow’s milk. It is not surprising that milk has such positive effects on recovery after a period of weight loss, as it has evolved as a food to support the offspring during a period of immaturity, vulnerability and high growth velocity. The aim of this review is to describe the effects of using cow’s milk in treating undernutrition in a developing country setting, with focus on children below 5 years. The potential effects of the most important constituents of milk, the type of milk products used in foods for treating undernutrition and current recommendations on using milk in these foods will be discussed. Although milk-based products seem to be very effective in treating and preventing undernutrition, the cost of cow’s milk is so high, compared to the resources available, that it is often not feasible to use products with high milk content for treating the many millions of children with undernutrition.

**Definition of Undernutrition**

Among children, wasting is defined as a weight-for-length/height (W/H) below −2 SD, based on the new WHO Growth Standards (www.who.int/childgrowth). Wasting can be divided into severe wasting (W/H < −3 SD) and moderate wasting (W/H between −2 SD and −3 SD). Stunting is defined as a height-for-age (H/A) below −2 SD and can also be divided into severe (H/A < −3 SD) and moderate (H/A between −2 SD and −3 SD). Underweight refer to children with a weight-for-age (W/A) below −2 SD. However, underweight is not a very useful classification, as low weight can be caused either by wasting, or by stunting or a combination of wasting and stunting. Children with bilateral pitting edema are always classified as severely undernourished, despite a W/H above −3 SD. The terms malnutrition and severe malnutrition was used previously, but since the term malnutrition in principle also includes obesity and other nutritional disorders, there has been consensus to use the term undernutrition for those with a low weight and/or height.

**Size of the Undernutrition Problem**

Undernutrition is widespread among children. According to recent estimates based on the new WHO Child Growth Standards, 178 (32%) of the 555 million children in the world below 5 years of age are stunted, while 112 million (20%) are underweight, and 55 million (10%) wasted [1]. Of the 55 million children with wasting, 19 million are severely and 36 million moderately wasted.
Why Is Milk So Effective?

Maternal milk is the only food mammals receive during the early period of life when growth velocity is very high and the composition seems optimal to support a high rate of tissue synthesis, which is important for children recovering from undernutrition. The components of cow's milk that are especially important for growth are protein, minerals and lactose, while cow's milk fat is usually not used in the products for treating undernutrition. In comparison with plant-based foods, another important quality of cow's milk products is that they contain no antinutrients or fibers.

Protein

Milk protein has a very high quality. FAO/WHO have recommended the protein digestibility-corrected amino acid score (PDCAAS), as the method to evaluate protein quality. This score is calculated from the first limiting essential amino acid needed in children recovering from undernutrition, and milk is the food with the highest PDCAAS score, about 120% [2]. Furthermore, the protein fraction contains peptides and other bioactive factors, which might have specific effects on growth and recovery from undernutrition. These constituents are especially high in whey products. However, it has not been shown convincingly that products based on whey have advantages over dried skimmed milk (containing 20% whey and 80% casein) in treating malnourished children [3].

Lactose

The high lactose content in cow's milk may have a positive effect on growth. The concern for symptoms due to lactose intolerance is probably unjustified as undernourished children seem to tolerate products with a high lactose content well [4] and a meta-analysis showed that even children with mild acute diarrhea can safely continue with milk products [5]. Furthermore, Torun et al. [6] showed no further beneficial effect with regard to nutrient absorption during recovery from malnutrition when comparing cow's milk products with hydrolyzed lactose to products with lactose. The positive effects could be due to a prebiotic effect of lactose entering the large intestine, improved absorption of minerals and beneficial luminal effects [7, 8]. Furthermore, regular consumption of milk will upregulate the lactase content in the intestine and thereby facilitate digestion of lactose, as pointed out in the paper by Savaiano [9]. In some animal studies, the positive effect of whey on growth has been ascribed to the lactose fraction [10, 11].
The therapeutic milk diets F75 and F100, shown to be very successful in the treatment of severely malnourished children, contain 1.3 and 4.3 g lactose per 100 ml, respectively. For comparison, ordinary cow’s milk contains about 4.5 g per 100 ml, and the content in breast milk, which is the best food to give to a child with undernutrition and/or diarrhea is much higher, about 7 g per 100 ml.

Minerals

Milk is an important source of growth-supporting minerals, also referred to as type II nutrients, such as potassium, magnesium, phosphorus and zinc. These minerals are especially important during catch-up growth after a period of weight loss [12]. Since there is no body store of type II minerals, except in the functional tissue, these minerals will be lost as the tissue is broken down. During catch-up growth, all type II minerals will have to be available in balance to build up lean body mass. If one of these nutrients is deficient in the diet, the child will stop growing and instead gain fat mass, if sufficient energy is provided [12, 13]. Cow’s milk contains all the type II minerals, and the bioavailability of the minerals is high compared with plant sources. The high bioavailability of the milk minerals is especially important for the undernourished child since the acid secretion of the stomach, which promotes absorption, often is low or even absent [14]. Malnourished children often present with clinically relevant phosphate deficiency [15, 16], which has been shown to be related to the prognosis [17]. According to Golden [12], the high bioavailability of phosphorus in milk, compared to plant sources, is likely to be partially accountable for the success of milk in the treatment of malnutrition. Plant source foods are often high in phytate, which contains phosphate in a form that is not easily absorbed, and phytate also inhibits the absorption of some of the other type II minerals [2].

Effects of Milk on Nutritional Status

Milk has some of the advantages that are characteristic of animal source foods. These advantages are described in detail in the paper by Allen and Dror [18]. They conclude that the few randomized studies available from low-income countries investigating the effect of milk mainly have shown an effect on growth, especially in the younger children, while the effects on cognitive function and physical activity were more pronounced in children receiving meat. They also emphasize milk as an effective agent in increasing vitamin B₁₂ status in populations with a high prevalence of vitamin B₁₂ deficiency.

In studies of treatment of children with severe wasting, the use of milk-based products has been shown to improve recovery considerably, and in
some studies, mortality was reduced from about 30 to 5% [19, 20]. Although milk is a major ingredient in the tested products and is likely to play a major role, other nutritional aspects of these products are also important, especially the mineral composition, which is designed to cover the needs for tissue synthesis during periods with a very high weight gain [19].

A specific positive effect of milk on muscle mass would be valuable in undernourished children. Some studies suggest that drinking milk immediately after endurance training will increase muscle mass [21]. The evidence for such a specific effect on muscle mass in children with undernutrition is not available. However, very few studies have examined body composition during treatment of children with undernutrition.

In addition to the well-documented effects on weight gain, which has been a main outcome in most studies of treatment of children with undernutrition, there is strong evidence that milk also has a specific effect on linear growth. This is discussed in detail in the paper by Molgaard et al. [21] and in the review by Hoppe et al. [22].

**Cow’s Milk Products Used in Treatment of Undernutrition**

When cow’s milk is used in treatment of undernutrition, it is almost always as a powdered product used as an ingredient in a special food. The most commonly used product is skimmed milk powder (SMP), which is more widely available than whey products. Whole milk powder is seldom used because it is more expensive and has a short shelf life, since the fat easily turns rancid. Other alternatives are different types of whey. The most common whey products are sweet whey powder with 13% protein and 75% lactose, and whey protein concentrates which are produced with 34% (WPC34%) or 80% (WPC80%) of the content as protein. WPC34% has a lactose content of about 50%, the same as SMP, while WPC80% contains only 10% lactose. Compared to SMP, whey may have specific beneficial effects on the immune system and on muscle synthesis, but evidence is lacking in children with undernutrition [3].

The high cost of milk is an important limiting factor, because resources for treating children with undernutrition unfortunately are very limited. Prices for the most common milk products, expressed as price in USD per kg protein, were for the first quarter of 2010 about USD 7 for both SMP and WPC80 (www.dairyforglobalnutrition.org). WPC34% is slightly cheaper, about USD 6 per kg, but has previously been 20–25% cheaper than SMP. Although these prices are for bulk and cost for transport will be added, it is thought provoking that translating this into a cost per liter for the same protein content as cow’s milk, the price is only about 20 cents per liter (1 kg of WPC34% protein dissolved in 30 l of water with a final protein content about 35 g/l).


**Products for Treating Undernutrition**

Since the mid 1990s, F-100 has been the preferred product used for treatment of severe undernutrition [19, 23]. F-100 contains SMP and whey, vegetable oil, sugar, maltodextrin, and a mineral/vitamin mix. Thus, 100% of the protein comes from milk. Another successful type of products for treatment of children with severe and moderate undernutrition is ready to use therapeutic foods, especially the milk and peanut butter-based product manufactured under the trade name PlumpyNut, in which about 50–60% of the protein content comes from SMP and whey [24, 25].

Corn Soy Blend (CSB) has been used for treatment of moderate undernutrition, but there is now consensus that this is not a suitable product for treatment, as the content of antinutrients and fiber is too high and it contains no animal protein [26]. An improved CSB, which has an 8% content of SMP, has been developed by WFP for children from 6–24 months [26]. It also has a higher oil and sugar content and thereby a higher energy density, and an improved vitamin-mineral blend, compared to the conventional CSB. However, the price of this improved CSB is also considerably higher than the price of the conventional CSB, and results from intervention studies are needed to document that the effectiveness of improved CSB can justify the higher price.

**Potential Negative Effects of Using Cow’s Milk**

If cow’s milk products are used in the treatment of infants and young children with undernutrition, there is a potential risk that intake of breast milk is reduced. In children with undernutrition, the positive effects of breastfeeding, especially in protection against infectious diseases are very important [27]. It is therefore crucial that mothers are supported and encouraged to breastfeed as much as possible. Guidance on how to support breastfeeding in these situations is given in the IMCI manual [28].

Another important issue is that powdered milk products should never be distributed to families with malnourished children as the risk of contamination during reconstitution in most settings is very high. If products like SMP are available in emergency settings, they can be used to fortify cereals or fortified blended foods, such as CSB used for preparing gruels, porridges or bread. If liquid cow’s milk is available, it should only be used if it is full fat milk, as products with low fat content will have a relative protein content that is too high. Undiluted cow’s milk has a high content of protein and macrominerals, approximately three times as high as in breast milk, which results in a high renal solute load if given in large amounts, which can result in hypernatremia and dehydration. Liquid cow’s milk should therefore not be given undiluted to infants.
Table 1. Conclusions and recommendations

**Conclusions and recommendations on milk in treatment of moderate malnutrition**

Liquid milk and milk powder are good sources of high-quality protein and micronutrients important for growth.

The minimum amount of milk protein needed to improve growth in children with moderate malnutrition 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 (SMP or whey protein concentration 34%) per 1,000 kcal will provide 25–33% of the recommended protein intake (24–26 g/1,000 kcal).

Milk is likely to be more effective than meat in treating moderate stunting, as milk has a special effect on linear growth through stimulation of IGF-I production.

Powdered milk with reduced milk fat, such as SMP 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 it 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 with SMP, but these effects have not been documented in children with moderate malnutrition.

The effects of using whey instead of SMP in the treatment of children with moderate malnutrition should be tested in intervention trials, both because whey protein concentrate is cheaper than SMP and because of the potential beneficial effects of whey.

Whole-milk powder should be used as a drink for children with moderate malnutrition only if it is prepared under strictly controlled and hygienic conditions.

If milk is the only animal source food given, sufficient iron should be provided in the diet.

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 SMP in the treatment of children with moderate malnutrition.

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1 These conclusions and recommendations are from the review by Michaelsen et al. [2] prepared for the WHO/UNICEF/WFP/UNHCR consultation on the management of moderate malnutrition in children under 5 years of age held in Geneva 2008.
Recommendations on the Use of Milk in Treating Undernutrition

There is consensus that children with severe wasting should be treated with products with high milk content, such as F-100 or ready to use therapeutic foods, as these products have shown to be very effective in supporting weight gain and reducing mortality [29]. The need for milk-based products in treating the 36 million children with moderate wasting is not clear. At the WHO/UNICEF/WFP/UNHCR meeting 2008 in Geneva on management of moderate malnutrition, it was concluded that animal-source foods added to a plant-based diet promotes recovery, but also that there was a need to study to which degree plant-based foods with a high energy density, and low content of antinutrients and fibers can be effective in promoting recovery [30]. As the importance of minimizing the costs of foods for children with moderate malnutrition was underlined, one of the research recommendations was to identify the minimum quantities of animal-source foods needed in the diets of children with moderate undernutrition to make a significant impact on recovery. One of the background papers for the meeting provided a detailed description of foods and ingredients used for children with moderate undernutrition and also covered milk and milk products [2]. The conclusions and recommendations from the section of milk and milk products are given in table 1. A general recommendation from the meeting was that studies of recovery from undernutrition should not only focus on weight gain but also assess linear growth, body composition, physical activity, and cognitive development as well as immunocompetence, micronutrient status, renal concentrating ability, and sodium pump function [30]. Such studies will provide a better understanding of how to compose a diet for children with undernutrition which not only provides weight gain but also optimal development and health.

References


**Discussion**

*Dr. Johansson:* I can give you one more argument for a change from maltodextrine to lactose. It relates to the pH drop in the tooth biofilm and risk of caries development. Maltodextrine gives as deep a pH fall as sucrose, whereas lactose does not cause a significant pH drop. So switching carbohydrate type would be tooth saving, and especially in malnourished children who are more prone to caries development.

*Dr. Haschke:* You presented products and product concepts. Maybe you can also elaborate on the outcome of trials which you have been conducting or you are aware of. What is the best practice in that segment, and what are the outcome variables that you consider clinically most relevant?

*Dr. Michaelsen:* There are many difficult problems within logistics, policies and economy when you distribute food and treat malnourished children. With limited resources, it is often necessary to choose between treating fewer children with an optimal food or more with a cheaper and less optimal food. Concerning outcomes, when you are talking about severe malnutrition the immediate and most important outcome is mortality, and we have now products that can reduce mortality to a very low level. Weight gain is used widely and is important because it is related to morbidity, but we should start to focus more on other outcomes like linear growth, body composition and functional outcomes. If weight gain is mainly body fat, it will not be advantageous in the long run. We also want to look at outcomes like physical activity and mental development. We would rather have them gaining a little less weight and running around playing than sitting in a corner being more fat.

*Dr. Prentice:* Over the years, there have been a number of preparations to add to these relief foods either to improve micronutrient status or digestibility, for example amylase and multimicronutrient mixes that are placed on food. Now there are these new improved fortified blends, would one use the older preparations, do they become redundant, or are they used with them as well?

*Dr. Michaelsen:* There is certainly a place for adding micronutrient supplements. But the mix used is changing and improved. There is also increased focus on the effects of antinutrients and fibers in the plant-based foods used. Therefore, enzymes like amylase and phytase added to the foods can have positive effects, but this is still being investigated. After the workshop in Geneva in 2008 on treatment of moderate malnutrition, there has been more focus on food technology and processing to make plant-based foods more acceptable and digestible for the young children who have a more vulnerable intestinal tract.

*Dr. Garg:* This is regarding the effect of lactose and reduction in NEC which has been shown in the preterm piglets study. The preterm formula which we use has 50% lactose, and 50% of the carbohydrate content consists of glucose polymers. Lactase activity in preterm babies is less, around 30% of a full-term baby, even at 34 weeks. How could the same information which is there in piglets, be clinically translated for preterm neonates as far as lactose content in the preterm baby formula is concerned?

*Dr. Michaelsen:* I am not a specialist in nutrition of preterm infants, and I think it's a question about balance. If you have lactose instead of maltodextrin, you also have a
problem with higher osmolarity, so I think you have to balance these things; but I also think it’s important to have some lactose, but I couldn’t say at exactly which level it is acceptable. I think that many formulas used in clinical nutrition and in prevention of allergy contain no lactose because there has been an exaggerated fear of lactose intolerance.

*Dr. Anderson:* My questions relate to the composition of some of the products. First, I was surprised that whey protein isolate in your scale of cost was so much less than the dried skimmed milk, and maybe you can explain that. Second, what is the target level of protein in relation to calories in those supplements?

*Dr. Michaelsen:* In these products, you shouldn’t have much more than 10–11% of the energy as protein. You don’t want to go too high both because of the cost but also because there might be a metabolic disadvantage, and a high protein intake might have a negative effect on appetite. Concerning the price, there is a large difference between whey protein isolate, which is very expensive, and whey protein concentrate 34%, which is the cheapest when calculated according to protein content, and it’s actually cheaper than sweet whey. Whey protein concentrate is cheaper than skimmed milk powder because it’s a surplus product from cheese production. At present, it is 20–30% cheaper than dried skimmed milk, but world market prices are constantly fluctuating.

*Dr. Sarwar Ferdaus:* Malnourished patients always suffer from gastroenteritis and diarrheal disease, so their intestinal villi are already short. What we have seen is that if we give milk alone, it’s less tolerated than if we mix it with other food, especially with rice. Could you comment whether we should give milk alone or mix it with other food or make a formula in such a way that lactose is reduced to some extent to promote better absorption?

*Dr. Michaelsen:* In F75 there are cereals and the milk content is reduced considerably, so that’s what you would give in some settings in the first week. There, you would have considerably lower lactose. And I am not saying that lactose intolerance cannot be a problem in individual patients. I am just saying that the experience from using F100 in many treatment centers is that it works very well in the majority of these children. Some children might not tolerate the high levels of lactose from the beginning, but giving them small amounts of lactose has a beneficial effect on their lactase levels.

*Dr. Bodenstab:* I would like to have your views on what industry such as Nestlé could do for you. I am thinking of supply of products using the purchasing power, our manufacturing set up and distribution. I am also thinking of using our R&D system to codevelop products. Conceivably, these products could be nonbranded or branded in a way that would be different from our normal branding.

*Dr. Michaelsen:* There are many technological aspects that need to be developed further, and I am sure that you would have a lot of knowledge that could be used in these settings. Again, the cost of the products is crucial. We need low-cost products and we need products that can be locally produced. Issues like the optimal composition of micronutrient supplementation, the potential use of enzymes in fortified blended foods, and the effects of food processing are areas where large companies like Nestlé will have knowledge that could be used in developing these products further.

*Dr. Boukari:* Can you tell us about rice milk, what is its energy and protein content?

*Dr. Michaelsen:* The only thing I know is that the rice milk you buy in Denmark has extremely low protein content. The Danish National Board of Health have come up with a statement saying that it is dangerous to give rice milk to small children. In Denmark, we have seen a tendency that mothers use more soy milk and rice milk. It is a completely different issue to add rice as a cereal in foods for treating moderately
malnourished children. Rice has a high protein quality and a low content of antinutrients, but is also relatively expensive compared to other cereals.

Dr. Savaiano: Can I have a comment to that? For healthy adults and probably children, it’s the only carbohydrate that doesn’t cause fermentation in the colon. So, if the small bowel is working, none of the carbohydrate should get to the colon, that should be an advantage, I would think.

Dr. Haschke: You probably were referring to commercial products which should also be available in developed countries. I can say that one product based on hydrolyzed rice protein is safe (Risolac) but in the high-price segment.

Dr. Boukari: About rice, the problem with that product is that it’s not largely distributed, and we can’t have that product in some countries like Maghreb with medium undernutrition. We don’t need cheap products but products for that kind of undernutrition and perhaps with a medium price. In some hospitals in our country, we use very expensive products with highly hydrolyzed protein. To have a high density of energy like 1 cal/1 ml, we use a high concentration, so it becomes very expensive. Perhaps for that country we need to use a product with a reasonable price, and perhaps industries like Nestlé or others have a role to play in that kind of malnutrition.

Dr. Thorsdottir: I was thinking about the age of the children and infants. Were you only looking at very young infants or older children as well?

Dr. Michaelsen: When the WHO and the UNICEF approach the topic of malnutrition in children, they usually focus on children below 5 years, but the younger you get the bigger the problems are. So it’s especially from 6 months to 2 years that you have a vulnerability that is much greater than later on. But very malnourished 3- or 4-year-old children might have the same problems as younger children.

Dr. Adrianasolo: If I understand you well, this treatment is intended for children whose weight for height is below –3 z score. What about the children with kwashiorkor, with edema, whose weight for height might not necessarily be below –3 SD?

Dr. Michaelsen: I didn’t include that in my definition, but severe malnutrition includes any child with edema, so it’s a weight for height below –3 SD or edema. If you have edema, you are always severely malnourished according to the official recommendations, even if your weight for height is above –2 SD. But in my talk I also covered children with moderate malnutrition, which is defined as a weight for height between –3 SD and –2 SD.

Dr. Begum: You mentioned that you added vegetable oil to skim milk. My first question is, is vegetable fat better tolerated than animal fat by the malnourished child? And to my second question, you have mentioned that F75 and F100 are not available in some Asian countries; in that situation, which food should we add to the milk?

Dr. Michaelsen: Regarding the type of fat, the reason that in all these products you don’t have milk fat is because it would go rancid, so from a logistical point of view it’s much easier to export and transport products like dried skimmed milk and whey powder with no fats and then add the vegetable fat later. By adding vegetable oils like soybean oil, you will also get a quite fine balance of n-3 and n-6 fatty acids. Your second question, what to use when you do not have F-75 and F-100 available, is quite complex, and I have no short answers. You could either use clinical products for enteral nutrition, which are quite expensive or you can get some guidance in our review on which foods to use in treating moderate malnutrition [1].

Dr. Sankaranarayanan: The different milk-based recipes you showed are all simplified, but in practice we find it very difficult to match a particular diet to the needs of a child. It’s not only children with diarrhea that I’m talking about. It concerns most of the patients with edema and extreme protein malnutrition who are totally anorexic. They have extreme loss of appetite and don’t accept any food.
Dr. Michaelsen: There are a lot of specific problems when you deal with an individual child, and if he/she has no appetite, you have to consider tube feeding. And there are a lot of details you have to consider, depending on how the child reacts to the treatment.

Dr. Sankaranarayanan: What we are faced with in these children is a triad of extreme risk factors, i.e. malnutrition, malabsorption and infection. But what is inevitable in these children is malabsorption plus malnutrition, so what is the recipe we can use?

Dr. Michaelsen: Malabsorption is almost always a problem in these children, and that’s part of the reason why milk is advantageous because many of the substances are easily absorbed. Still, you might have individual children with specific malnutrition problems that you have to deal with and you might have children that have milk allergy, and so there are a lot of specific problems when you are confronted with a specific child that I was not able to cover here.

Reference
