Effects of Animal Source Foods, with Emphasis on Milk, in the Diet of Children in Low-Income Countries

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Abstract

This review evaluates evidence for benefits of including animal source foods (ASF) in the diets of children in developing countries. In observational studies, a higher usual intake of ASF in such countries is associated with better growth, status of some micronutrients, cognitive performance, motor development and activity. Only three randomized trials supplemented children with milk and compared outcomes with a nonintervention control group. Both height and weight growth were improved, although in Kenya height was increased only in younger schoolers who were stunted at baseline. Meat supplements have been evaluated in only two randomized controlled trials, in Kenya and Guatemala (mean baseline age 8 years and 1 year, respectively); growth was no better than in an equicaloric control group. Meat improved cognitive function and activity in Kenya; milk was less effective than meat for improving cognitive function and physical activity, perhaps due to its lower content of iron, zinc, or riboflavin. Meat and especially cow’s milk are excellent sources of vitamin B₁₂, a micronutrient commonly deficient in populations which consume low amounts of ASF. Other micronutrients such as iron have been added to cow’s milk and resulted in improved nutritional outcomes for children.

Introduction

Animal source food (ASF) intake in developing countries is often very limited. According to FAO, ASF provide <5% of total energy intake in many countries of sub-Saharan Africa, 5–10% in most other African countries and southern Asia, 10–15% in eastern and northern Asia as well as Mexico, and ≥20% in the US, Canada, Europe and Australasia. Plant-based diets, high in
phytate and fiber, are often lower in energy density, provide poorer quality protein, and are low or completely lacking in some essential micronutrients [1, 2]. Per 100 g, whole cow’s milk provides 0.36 µg vitamin B₁₂, 138 IU vitamin A, 0.16 mg riboflavin, 5 µg folate, and 119 mg calcium [3]. Meat provides substantial amounts of available iron and zinc, riboflavin, and vitamin B₁₂ [4]. The provision of multiple micronutrients simultaneously can be especially advantageous; for example, vitamin A and riboflavin enhance iron mobilization and hemoglobin synthesis. Vitamin B₁₂ is found only in ASF, explaining the high global prevalence of deficiency in most developing countries [5]. The focus in this article is on demonstrated benefits of including ASF in the diets of children in developing countries. Here ‘milk’ refers to cow’s milk, and not to human milk or infant formulas, unless otherwise stated.

Interpretation of the literature on the importance of ASF in children’s diets is complicated by the many study designs used to investigate this question. These include: observational studies, with and without separation of milk from other ASF; interventions with: milk vs. nonintervention control; milk vs. an equal amount of energy; milk vs. meat, with and without a nonintervention control, and fortified milk vs. unfortified milk or a nonintervention control, vs. several other types of intervention.

**Observational Studies**

There is little doubt that infants and young children who receive more ASF in developing countries usually have better growth, cognitive performance and motor function. ASF are the only, or a major, source of many micronutrients that support children’s growth and development as well as the protein and other bioactive factors discussed elsewhere in this book.

Older studies of the adverse effects of macrobiotic diets on child development in The Netherlands are informative, because such diets are similar to – or arguably poorer than – those of some children in some developing countries (cereals, rice, vegetables, legumes, and small amounts of cooked fruit and fish, but no meat or dairy products). In the Dutch situation, there was also less confounding by illnesses resulting from poor local unsanitary conditions. Compared with omnivorous controls, the macrobiotic children’s intakes of protein, fat, calcium, riboflavin, vitamin B₁₂ and vitamin C were lower. Although birthweights were smaller (3,290 vs. 3,470 g), growth was normal until age 4 months, at which point it declined dramatically (13.2 cm/year compared with 16.7 cm/year in controls). It stabilized at 16 months, but there was no catch-up later [6]. Children from families who consumed dairy products three times a week grew better than those who consumed them rarely. The macrobiotic infants had a substantially higher prevalence of iron, riboflavin and vitamin B₁₂ deficiency, anemia and rickets [7]. They had delays in gross motor development, speech and language development. Vitamin B₁₂
status and cognitive function was still poorer than that of controls in early adolescence, although parents heeded advice to feed ASF, starting at age 6 years on average [8].

An analysis of the Demographic and Health Survey data from seven countries in Latin America revealed that milk intake was significantly associated with better length- or height-for-age z scores in all countries, while meat intake showed this association in only one country. However, it is possible that the range and amount of meat intake in the other countries was inadequate to reveal any associations with usual consumption [9]; in rural Kenyan schoolchildren, there was no association between ASF intake and adequacy of intake of micronutrients until additional amounts of ASF were added to the diets through supplementation [Allen et al., unpubl. data].

Usual ASF intake, expressed as percent of total energy, was the main predictor of many outcomes in the observational Nutrition Collaborative Research Support Program conducted in Egypt, Kenya and Mexico during the 1980s, including growth, affect, cognitive function, physical activity, and micronutrient status of children [10]. In an earlier study in Kenya, animal protein intake at 18–30 months of age was a stronger predictor of cognitive function 5 years later than was total protein intake [11]. Similar results were found amongst Egyptian children [12]. Associations with milk vs. meat were not analyzed separately. In Peru, linear growth between 12 and 15 months of age was positively associated with intake of ASF in children with a low intake of complementary foods, but again there was no separation of milk vs. meat in the analysis [13]. In Nepal, children with high meat or fish intake at age 13–24 months were significantly less likely to present with vitamin A deficiency-associated xerophthalmia at age 1–6 years [14].

**Intervention Trials**

A limited number of randomized, controlled intervention trials have been performed to determine the effects of adding ASF to the diets of young children. A review of the efficacy of different ASF interventions in improving child growth concluded that supplements containing at least some dried milk improved children’s growth in twelve of fifteen studies [15]. Outcomes usually measured include growth, micronutrient status, cognitive performance, and/or level of physical activity. Studies are presented by type of intervention design, as far as possible (table 1).

*Interventions with Milk, Meat or Fish vs. a Nonintervention or Equicaloric Control Group*

Surprisingly few investigators in developing countries have fed milk to one group of children and compared outcomes with a nonintervention control group; only three such studies were identified. Some 40 years ago, the benefits
<table>
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<tr>
<th>Reference</th>
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<th>Subjects</th>
<th>Age at entry</th>
<th>Intervention</th>
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<tr>
<td>[16]</td>
<td>New Guinea</td>
<td>33</td>
<td>7–8 years</td>
<td>Daily for 13 weeks 1. 75 g skim milk + normal diet 2. Normal diet (high in taro and sweet potato)</td>
<td>– Height and weight change in control group = twice that of controls</td>
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| [17]      | Bac Ninh province, Vietnam | 454      | 7–8 years    | 6 months, school days only 1. 500 ml unfortified milk 2. 500 ml MMN fortified milk providing 5.5 mg Zn, 6.5 mg Fe, 6.7 µg vit. A, 165 mg vit. C, 13 mg vit. E/d 3. Control (no supplementation) | – Weight-for-age and height-for-age z scores improved significantly in both milk groups compared with control  
- Short-term memory scores significantly higher in children in milk groups, with superior scores in fortified milk group  
- Parent reported health-related quality of life improved with milk intervention |
| [1, 19]   | Embu district, Kenya | 544      | 5–14 years   | 7 school terms (2.25 years) daily 1. Githeri (maize and bean-based porridge) with finely ground beef 2. Githeri with one glass UHT milk 3. Githeri with added vegetable oil 4. Control (no supplement) | – Significant increase in plasma B₁₂ in meat and milk groups  
- Significantly increased weight gain in all supplemented groups  
- Significantly better performance on arithmetic tests and highest level of physical activity in meat group |
| [26]      | Guatemala City   | 302      | 12 months    | 9 months, supervised feeding at 1 meal/day, 5 days/week for 9 months 1. Ground beef (72 g, 102 kcal/day, providing 0.56 µg B₁₂) 2. Fruit + vegetables (92 kcal/day, fortified with 0.86 µg B₁₂) 3. Fruit + vegetables, unfortified, (92 kcal/day) | – No effects of beef or B₁₂ fortification on any child outcomes in a B₁₂-deficient population  
- Cow's milk intake from usual diet positively predicted B₁₂ status, while breast milk intake was a negative predictor |
<table>
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<tr>
<th>Study</th>
<th>Location</th>
<th>Sample Size</th>
<th>Age (years)</th>
<th>Intervention Duration</th>
<th>Details</th>
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<tr>
<td>[29]</td>
<td>Mangochi district, Malawi</td>
<td>630</td>
<td>2.5–7.5</td>
<td>12-month dietary diversification strategy including 1. Increased consumption of ASF (especially whole dried fish) and orange-red fruits 2. Control (no intervention)</td>
<td>Significant improvement in mid-upper-arm circumference, z score and reduced prevalence of inadequate vit. B&lt;sub&gt;12&lt;/sub&gt;, Ca, and Zn intake after intervention Hb significantly higher, incidence of anemia and common infections significantly lower in intervention group than control</td>
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<td>[30]</td>
<td>Peri-urban Lima, Peru</td>
<td>137</td>
<td>12–17.9</td>
<td>9 months 1. Community-based, behavioral and dietary intervention to increase heme iron, total iron and ascorbic acid intake 2. Nonintervention</td>
<td>Significant increase in total and heme iron intake (heme iron to 0.66 mg/day vs. 0.21 mg/day baseline) No significant effect on anemia but prevented increase seen in control group</td>
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<tr>
<td>[27]</td>
<td>Ghana</td>
<td>208</td>
<td>6 months</td>
<td>6 months, daily; local cereal from maize, soy, peanuts 1. Cereal + 20% whole fish powder 2. Cereal + MMN 3. Cereal 4. Cross-sectional nonintervention</td>
<td>No significant effects among intervention groups on weight or length gain, hematology, or iron, zinc or riboflavin status Growth poorest in nonintervention group</td>
</tr>
<tr>
<td>[28]</td>
<td>Northern Cape province, South Africa</td>
<td>183</td>
<td>7–9 years</td>
<td>6 months, school days only 1. 25 g bread spread containing marine fish flour (892 mg DHA/week) 2. 25 g bread spread without fish flour</td>
<td>Significantly higher EPA and DHA levels and cognitive function (verbal learning ability and memory) test scores in experimental group compared with control</td>
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MMN = Multiple micronutrient; EPA = eicosapentaenoic acid; DHA = docosahexaenoic acid.
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<td>[31]</td>
<td>Mexico</td>
<td>227</td>
<td>8–60 months</td>
<td>90-day supplementation with 500 ml fortified milk containing 22.5 mg Zn, 1.5 mg Fe, 2,250 µg vit. A, 105 mg vit. C</td>
<td>– Significant improvement in weight-for-height z scores, plasma levels of vit. B₁₂, folic acid, and Hb</td>
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| [5, 33]   | Central and eastern Mexico | 567 | 12–30 months | 12 months daily  
1. 48 g fortified milk powder (5.3 mg Fe, 5.3 mg Zn, 48 mg vit. C), reconstituted to 400 ml  
2. 48 g unfortified milk powder (0.2 mg Fe, 1.6 mg Zn, 6.8 mg vit. C), reconstituted to 400 ml | – Prevalence of moderate anemia (Hb 90–100 g/l) and iron deficiency (serum ferritin <12 µg/l) significantly lower in fortified milk group at 6 and 12 months (no other measures) |
| [32]      | Puebla, Mexico | 115 | 10–30 months | 6 months daily  
1. 48 g fortified milk powder (5.3 mg Fe, 5.3 mg Zn, 48 mg vit. C), reconstituted to 400 ml  
2. 48 g unfortified milk powder (0.2 mg Fe, 1.9 mg Zn, 6.8 mg vit. C), reconstituted to 400 ml | – Significant decline in prevalence of anemia (41.4–12.1%) in fortified milk group, no change in unfortified milk group  
– Treatment with fortified milk significantly negatively associated with likelihood of anemia following intervention (no other measures) |
| [38]      | New Delhi, India | 633 | 1–3 years  | 1 year daily  
1. MMN-fortified milk powder providing 9.6 mg Zn, 9.6 mg Fe, 6.6 µg Se, 0.3 mg Cu, 330 µg vit. A, 48.0 mg vit. C, 8.1 mg vit. E/d  
2. Unfortified milk powder | – Fortified milk significantly reduced incidence of diarrhea, acute lower respiratory tract infection, and overall days with severe illness during study period  
– Differences in morbidity most pronounced in children <2 years old |
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<th>Study (Year)</th>
<th>Location</th>
<th>Duration</th>
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| [44]        | Dong Thap province, Vietnam | 6 years | 143 nonconsecutive days over 529-day period  
1. 150 ml vit. A and D fortified milk + MMN-fortified biscuits, providing 424 µg vit A, 5 mg Fe, and 6 mg Zn  
2. Control (no supplementation)  
- Small but significantly greater gain in weight and height in milk group compared with control over study period |
| [45]        | Tupa, Brazil      | 6 months to 2 years | 1 l/day Fe-fortified whole cow's milk (3 mg Fe) for 7.3 months  
- Hb normalized in 57% of subjects following intervention  
- Highest Hb repletion rate in severely deficient group, no change in children with normal status initially |
| [34]        | Buenos Aires, Argentina | 12–48 months | 4 months daily Fe-fortified fluid cow's milk (15 mg Fe/l), ad libitum  
- 100% of children achieved normal values for Hct, Hb, serum Fe, and transferrin saturation  
- Change in Hct and Hb significantly greater in children anemic at study entry |
| [35]        | Santiago, Chile   | 3 months | 12 months daily  
1. Full-fat fortified milk powder (15 mg Fe, 100 mg vit. C, 1,500 IU vit. A, 400 IU vit. D per 100 g), acidified with *Streptococcus lactis*, prepared as 10% dilution, ad libitum  
2. Full-fat nonacidified unfortified milk powder, prepared as 10% dilution, ad libitum  
- At ages 9 and 15 months, all measures of iron status (Hb, serum Fe, total iron binding capacity, transferrin saturation, free erythrocyte protoporphyrin, and serum ferritin) significantly higher in fortified milk group than control |
of adding 75 g skim milk daily to a control, normal diet (high in starch) were evaluated in New Guinea schoolchildren 7–8 years old [16]. Height increased by 2.3 cm during the 13-week intervention compared with 1.1 cm in the control group. In rural Vietnam, in a region where the prevalence of stunting was 50%, schoolers (age 7–8 years) were provided 500 ml of unfortified milk on school days for 6 months [17]. This milk increased energy intake by 278 kcal (20%) and protein intake by 13 g (40%). Weight gain was 0.5 kg greater and height gain 0.4 cm greater in the milk intervention group compared with the nonintervention controls, but these differences were not significant. The milk did significantly reduce underweight (by 13%, possibly due to the higher energy intake), stunting (by 2%) and the number of reported health problems. There was no effect on serum retinol or ferritin.

A well-designed study was conducted in rural Kenya, although participants were schoolers and not young children [18]. The area was known to be prone to food shortages and famines, with very low intakes of ASF (milk and meat combined providing only 1% of daily energy intake) and a high prevalence of stunting (30%) and multiple micronutrient deficiencies. Equicaloric (≈250 kcal/day) supplementation of 544 children aged 5–14 years (median 7.4 years) with traditional maize- and bean-based porridge (githeri) containing additional oil, meat (60–80 g/day), or milk (1 cup/day) over seven consecutive school terms (2.25 years) significantly increased weight gain by about 10%, compared with a nonsupplemented control group [1]. Energy and protein intakes were adequate and similar in the three intervention groups. Milk supplementation had a significant effect (a 15% greater increase compared with the control group) on height gain in those children who were younger and already stunted, while meat supplementation was the only intervention that increased lean body mass. In an analysis taking into account the total dietary energy food intake of the children and controlling for sex, age, and socioeconomic status, growth was positively predicted by energy and nutrient intakes from milk or meat. Plasma vitamin B₁₂ increased significantly in both the milk and meat intervention groups; prevalence of combined severe and moderate deficiency (plasma B₁₂ <221 pm) fell from 80.7 to 64.1% in the meat group and from 71.6 to 45.1% in the milk group, after 2 years of intervention [19]. No improvement was found in other micronutrients in the same intervention groups, though changes may have been obscured by malaria and other infections [4]. Both height and weight gain were positively predicted by average daily energy intake from ASF, heme iron, preformed vitamin A, calcium, and vitamin B₁₂, while gain in muscle mass was predicted by average daily energy intake from ASF, and vitamin B₁₂ intake [20].

Cognitive status of the Kenyan schoolers was assessed repeatedly using a variety of tests that measured abstract reasoning, problem solving, arithmetic skills, verbal skills, and recall of number sequences. After 2.25 years of supplementation, the meat intervention group performed significantly better than the milk intervention and control groups on arithmetic tests, and showed
significantly greater gains in the Raven’s Colored Progressive Matrices (RPM) test, which evaluates abstract reasoning and problem solving skills. In contrast, the milk group had the lowest rate of increase in RPM scores. At the end of the intervention, there were no significant differences among groups in verbal skills or recall of numeric sequences, but the meat group showed significantly better improvements in end of term test scores. Differences in the effects of meat and milk interventions on cognitive performance may have been related to their iron content, with meat providing bioavailable heme iron that also enhances iron and zinc bioavailability from cereals, while milk may have impaired iron absorption due to its calcium, phosphorus and casein content [1, 21, 22]. Micronutrients provided in the meat supplement may have contributed to increased processing speed; longitudinal regression analysis showed significant relationships between iron, zinc, vitamin B₁₂ and riboflavin intake and improved cognitive test scores, after controlling for confounders [21, 23]. Activity level was assessed by observing schoolyard behaviors during unstructured play using the same methods as in the NCSRP. The meat group spent the greatest percentage of time in high levels of physical activity and had the largest decrease in percent time spent in low levels of physical activity. The milk group had less activity than in all but the control group [1, 24].

Vitamin B₁₂ is found only in ASF where diets are not fortified with this nutrient, and evidence has accumulated during the past two decades to indicate that this deficiency is highly prevalent in developing countries, affecting population subgroups with a low intake of animal products. This vitamin deficiency is highly prevalent in Guatemalan women, and their infants and children [25]. In collaboration with the Institute of Nutrition of Central America and Panama we conducted an intervention study to investigate the feasibility and efficacy of supervised equicaloric supplementation of children with meat vs. fruit and vegetables containing added B₁₂, vs. fruit and vegetables alone, 5 days a week from 12 months of age [26]. At the end of the study, there were no significant differences in growth, hemoglobin, ferritin, or plasma vitamin B₁₂ among the groups, or in cognitive or motor function, or any of several other measures of child development. At baseline (12 months of age) and after intervention, vitamin B₁₂ deficiency was associated with poorer cognitive function and slower motor development. The same children tended to be B₁₂ deficient at the beginning and end of the intervention. Breast milk at 12 months postpartum was seriously inadequate in vitamin B₁₂ with none detectable in about half of the samples. The infants’ usual intake of cow’s milk – usually reconstituted, unfortified dry milk – was a positive predictor of the infant’s vitamin B₁₂ status, while breast milk intake was a negative predictor. In the Kenyan trial that provided meat or milk to schoolers over a 2-year period, vitamin B₁₂ status was significantly improved but still did not reach normal values in many children [19].

A few trials tested the benefit of adding fish to children’s diets. The addition of 20% by weight of dried, whole fish to the local weaning food product
produced for complementary feeding in Ghana (based on maize, soybeans and peanuts) did not improve growth or micronutrient status compared with an unfortified group [27]. South African children aged 7–9 years were assigned to a fish flour spread or a placebo spread for 6 months to explore the benefits of a higher intake of n-3 polyunsaturated fatty acids for cognitive function. There were significant increases in eicosapentaenoic and docosahexaenoic acid concentrations in the intervention group and improved performance on learning and reading tests [28].

Dietary diversification and modification strategies have attempted to increase consumption of ASF. A trial to increase ASF (especially dried fish with bones) intake and reduce dietary phytate in Malawian children aged 2.5–7.5 years significantly improved z scores for mid-upper-arm circumference and arm muscle area after 12 months. There was no effect on weight or height gain compared with controls. The authors hypothesized that lack of ponderal or linear growth change in the intervention group may have been due to insufficient duration of the intervention, the age range of the children, or intergenerational effects of malnutrition [29]. However, the intervention reduced the prevalence of inadequate intakes of vitamin B₁₂, calcium, and bioavailable zinc. Additionally, mean hemoglobin concentration was significantly higher, and incidence of anemia lower, in the intervention group compared with the controls.

A community-based, randomized, behavioral and dietary intervention trial in Peruvian adolescent girls increased heme iron and ascorbic acid intakes considerably, but had no effect on hemoglobin or iron status although it prevented the fall in these indicators in the control group [30].

**Interventions with Micronutrient-Fortified Cow’s Milk**

In recognition of the fact that cow’s milk lacks substantial amounts of some micronutrients, but at the same time it is a relatively nutritious, affordable, available and well-liked food for children, considerable efforts have been made to evaluate the benefits of adding micronutrients to dry or liquid cow’s milk. Milk is well recognized to be especially low in iron, and impede absorption of other sources of dietary iron due to its high levels of calcium, phosphorus and casein, so most attention has been paid to improving its iron content.

Daily consumption of 500 ml/day of multimicronutrient-fortified whole milk for 90 days by 227 children aged 8–60 months in Mexico City significantly improved weight-for-height z scores and plasma concentrations of vitamin B₁₂, folic acid and hemoglobin. Per 500 ml, the fortified milk provided 1.5 mg iron, 3 µg vitamin B₁₂, 2 mg folic acid, and 22.5 mg zinc in addition to other micronutrients. There was no control group. The fortified milk was well tolerated and widely accepted [31]. A significant reduction in anemia prevalence, from 41 to 12%, resulted when Mexican children aged 10–30 months were given 220 g milk powder reconstituted to 400 ml and fortified with 5.3 mg iron, 5.3 mg zinc and 48 mg vitamin C, daily for 12 months. The control group received unfortified milk and showed no reduction in anemia [32].
Mexico has a large-scale program in which micronutrient-fortified milk is distributed to low-income children. An evaluation of the program showed the children consumed approximately 600 ml/month. While it is not possible to separate the effects of individual nutrients on outcomes, the provision of MMN-fortified vs. unfortified milk caused weakly significantly greater reductions in prevalence of anemia and iron deficiency [33]. Because the program included other interventions, it was not possible to separate the beneficial effects of milk from other benefits of the program.

Iron-fortified cow's milk also improves iron status of iron-deficient and/or anemic children in wealthier populations. In a study of 17 mildly iron-deficient Argentinean children aged 12–48 months, mothers were instructed to replace regular cow's milk with an iron-fortified fluid whole cow's milk containing 15 mg Fe/l. After 4 months of intervention with an average daily milk intake of 877 ± 310 ml, all children achieved normal values for hematocrit, hemoglobin, serum iron and transferrin saturation. There were no problems with tolerance or acceptance of the fortified milk [34]. The results agreed with those from earlier studies of iron-fortified milk products (powders and acidified milk) used to prevent or treat iron deficiency in infants and young children. In those studies, ascorbic acid was used to enhance the bioavailability of iron in fortified milks [35–37].

In a peri-urban area of northern India, 633 children aged 1–3 years were randomly assigned to receive multimicronutrient fortified or control milk reconstituted from powder three times per day for 1 year. The micronutrient-fortified milk was designed to deliver daily doses of 9.6 mg iron, 2.7 µg vitamin B12, 9.6 mg zinc, and 330 µg vitamin A. Compared with control milk, consumption of fortified milk significantly reduced the incidence of diarrhea, acute lower respiratory tract infection, and overall days with severe illness across age groups, although differences were most pronounced in children under the age of 2 years. Fortified milk was well accepted by the study population [38].

### Milk from Other Animals

In some developing countries, goats, sheep or buffalo are more accessible as household livestock than cows, and their milk may be perceived as more suitable for children. For example, children of the Gursum community in Ethiopia are often given goat milk as a supplement to breast milk [39]. Aside from containing more medium-chain fatty acids, the macronutrient composition of goat's milk is similar to cow's milk, and it has been used successfully as an alternative to cow's milk in short-term rehabilitation of undernourished children in Madagascar [40–41]. However, goat's milk is known to be deficient in folate (1 µg/100 ml compared with 5 µg in human and cow milk), and infants fed exclusively with goat's milk can present with megaloblastic anemia.
of folate deficiency [42]. The milk of sheep and buffalo has about 25% more protein and twice as much fat compared to cow's milk.

**Unresolved Questions Concerning Cow’s Milk and Children’s Health in Developing Countries**

Despite the numerous benefits of cow’s milk, there are some concerns regarding its use in the diets of children. These include its introduction at too young an age, iron depletion, an excessive renal solute load, and potential programming for metabolic imbalances later in life. Excessive cow's milk consumption has been implicated in energy displacement and deficiencies of micronutrients lacking in milk, especially iron. Occult intestinal blood loss is estimated to occur in 40% of normal infants less than 12 months of age during feeding of cow's milk [42], which could exacerbate the higher risk of iron deficiency in developing countries. The low DHA content of cow's milk vs. breast milk could also be an issue where usual intake of this nutrient is low. Compared with breast milk, cow's milk conveys a high renal solute load due to its protein and mineral content. Immaturity of the renal system in concentrating urine, in conjunction with low fluid intake or extrarenal water losses, can lead to severe dehydration in infants fed cow's milk. In developing countries, the prevalence of low birthweight and preterm delivery is substantially higher, and such infants have a less mature renal system. Milk is one of the most common food allergens in children, and little is known about its allergenicity in populations with compromised immune function due to undernutrition. There has been relatively little attention to these issues in developing countries, except for concern about its early introduction displacing breastfeeding. In most countries, including the US, introduction of unmodified cow's milk is discouraged until after the 1st year of life due to limitations in its composition and potential adverse effects on infant health.

**Conclusions**

While a higher usual intake of ASF by children is associated with a range of more positive outcomes, this review, limited to studies in developing countries, reveals that there have been few well-designed trials of the efficacy or effectiveness of increasing children's intake of ASF. Only three trials evaluated the benefits of unfortified cow's milk compared with a control. They all revealed improved gain in weight and in height – at least in stunted children. In the two trials in Kenya that supplied meat, it did not increase gain in weight but did improve cognitive function more than milk. Meat, and especially milk, is an important source of vitamin B₁₂ for children, and longer-term supplementation with ASF can improve B₁₂ status of children. This micronutrient
is deficient in many populations consuming low amounts of ASF, and inadequate amounts are obtained from breast milk of deficient mothers. Benefits of adding fish to children’s diets have been little evaluated, but there was no effect on growth or micronutrient status when it was added to a weaning cereal in Ghana. No trials evaluated the benefits of increasing egg intake. Cow’s milk can be a good fortification vehicle for micronutrients, such as iron, supporting its positive effects on child growth. Potentially problematic issues concerning the use of cow’s milk in children’s diets have been poorly explored in the developing country context.

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Discussion

Dr. Bhattacharya: I am very interested in the topic you have presented with regard to the population effect of borderline malnutrition. Your findings are very nice, especially the qualitative measures that you included like parents reporting fewer health side effects or teachers saying that the children are getting more active; I think they are very important issues to research in this part of the world. However, you showed how difficult it was to make the children eat beef. I think there must be another composite model, and I would be very interested to talk to you about this because I think there are certain solutions that we can exchange.

Dr. Allen: Thank you, I appreciate your comments. It actually took us months to get the recipe right so these little kids in Guatemala would eat this beef. Once we did, they loved it. The point you are making of course is that if we are talking about micronutrients and perhaps fatty acids and so on, how to do this, that of course is part of the rationale for all of these studies with lipid-based nutrient spreads. The idea is, you just take a teaspoon, or perhaps you take two teaspoons for older children and pregnant women and mix it with the normal food, and theoretically they are going to eat this happily for the rest of their life. It’s going to be very interesting to see this, but the idea is to give the concentrated source of these nutrients without large amounts of energy.

Dr. Bhattacharya: My point, being a developmental pediatrician, is how to get the food to them so that they accept it. I think we can work out a composite model which can be researched.

Dr. De Beer: I would like to find out more about the milk that you used in these trials, was it fresh milk? Did you ever consider powdered milk which in most cases is iron fortified? And have you ever considered the use of fermented milk in any of these trials?

Dr. Allen: In the Kenya trial, it was just fresh UHT milk. In Vietnam, it was also fresh milk in cartons. In New Guinea it was dried skim milk powder, I believe, so normally fresh milk. I don’t believe that anybody has shown that adding extra micronutrients to milk improves child development, but this is the basis, for example, of large national studies. For example, in Mexico the government is providing essentially dried milk fortified with micronutrients to the population, and that has been shown to improve growth of children and linear growth in the population. So you are right, when you read these papers, everybody is trying something different.

Dr. De Beer: And fermented milk?

Dr. Allen: I don’t know of any experience with that; there are no good intervention studies.

Dr. Mouane: I have a question about meat. Studies often talk about beef meat, but what about chicken meat? It’s more affordable.

Dr. Allen: Yes, I realize there are a lot of cultural aspects to these studies. Chicken meat, as far as I know, should be virtually the same in terms of its nutrient content. There have been education interventions in Peru and in Malawi. In Malawi, the participants were advised to increase fish intake and reduce phytate and so on, and in Peru
it was all sorts of animal source foods in a low-income community. In both of those, you saw improvements in iron status, but there were no other demonstrated benefits of the intervention. It’s very hard, unless you are doing a real intervention study giving this every single day, to see impacts of giving most foods. They are slow to show effects, and so the hope is that this would be somehow available for the usual diet of the population.

*Dr. Haschke*: I have a question concerning your reference values of vitamin $B_{12}$. If we consider the American or the European child as the reference, the Indian child will be substantially below that reference intake. But this does not necessarily indicate deficiency. In India, a substantial segment of the population consists of vegetarians. Shouldn’t we have reference values for the vegetarian child population, with no signs of $B_{12}$ deficiency?

*Dr. Allen*: That’s a very complex question and that’s of course exactly why I am trying to do the intervention studies to prove that it matters. If I compare the plasma levels of the Guatemalan infants with those from studies where the children have been clinically diagnosed as having delays and hypotonia and all the other symptoms of $B_{12}$ deficiency, certainly the ones in the deficient group are the same as those children in industrialized countries who have been revealed to have these different problems. So that’s part of my answer. Also I think that we don’t know all of the adverse effects of $B_{12}$ yet. The haematology is one of the last things to change, it’s not the right outcome to be looking at. Certainly in India, there is elevated methylmalonic acid showing metabolic insufficiency of $B_{12}$ in both the marginal and the deficient groups, and then there are all the concerns about epigenetics, methylation in pregnancy and risk of chronic disease and obesity in later life and so on. So vitamin $B_{12}$ is one of the more undiscovered nutrients, and you are absolutely right, we have to prove that these low levels are not healthy, and investigate the associations that they have with maternal depression, poor motor development and poor school performance, both in Kenya and in Guatemala.

*Dr. Haschke*: I would like to add something. My question was related to a nonmalnourished population with vegetarian eating habits. There is a debate whether vegetarian eating habits are associated with longer lifespan and better health. Therefore, being a vegetarian could be an advantage rather than a disadvantage.

*Dr. Allen*: Well, it depends on what age group you are talking about. I say it’s very clear that it is a disadvantage for young children; it may not be for older persons. It’s very important with $B_{12}$ to know that usual intake parallels serum concentrations. You don’t have to be a vegetarian, you can just avoid meat and be relatively deficient. So it’s a continuum, but regarding young children, the Dutch macrobiotic studies where some fish was consumed by children showed very greatly impaired development of those children. I think it might be a different case if you are talking about adult diseases and reducing risk of those diseases compared to having too much meat; moderation is the answer here.

*Dr. Fewtrell*: I just wanted to ask you about the acceptability, affordability and availability of the meat; for example, in your Kenyan population would they actually have access to meat beyond the period of the study, and would it normally be consumed by that population? Secondly, I wondered if you have any thoughts about the use of liver as a source of meat.

*Dr. Allen*: Very important issue. In that supplement of the *Journal of Nutrition* which I described to you, there are actually several papers talking about the feasibility of producing animals for meat and the effect on the economic status of the household. It doesn’t have to be beef, it can be chicken and so on. In these populations, this project actually was involved in increasing the production of dual purpose goats, for example, which was very successful, provided a living for the women, and providing
more meat for the community. This won't be possible everywhere and absolutely, I am not saying it is, but it is much more feasible than one might imagine. Growing chickens is another strategy which has been worked with local veterinarians to reduce poultry diseases. We tried that in Nepal and it was really quite successful in terms of increasing meat intake of children. It’s not something we should just discount out of hand as being impossible, and you should read the literature on how this can be a terrific boon for women in the communities in terms of increased income as well.

*Dr. Mohan:* In India, a majority of vegetarians drink milk; in fact, a lot of vegetarians eat eggs too. So, at least in my experience, we have not seen a lot of patients who have been taking milk to be $B_{12}$ deficient, but yes we do come across $B_{12}$-deficient children who do not take milk for reasons of taste. My question is, this 80% which has been looked into, which population was it, maybe a population that was not even taking milk?

*Dr. Allen:* These are results of Helga Refsum and Ranjan Yajnik, so probably around the Pune area in particular, but I think it was a mixture of children in Pune and the surrounding location.

*Dr. Mohan:* I would only say that that’s not a true representation of the country because we don’t get to see that, most of them do take milk.

*Dr. Adrianasolo:* My question is related to the methodology. Apart from meals given at school, did you also have controlled data on food eaten at home each day by each child?

*Dr. Allen:* There were 24 days of food intake for each child, actually 48 over the 2 years. So, yes, we had an enormous amount of data on that. There was a very slight increase in energy intake in the meat and milk group, but the calculation showed that that probably was expended in higher activity levels of those children. All of these results still remained controlling for usual intake, and the intake at home. The paper on that by Murphy is in that supplement to the Journal of Nutrition.

*Dr. Dehbi:* I would like to take the opportunity to make comments about nutritional problems. Research is very pertinent and is essential for us to improve our practice, but in developing countries milk and meat are very expensive and we cannot afford them. It’s not sufficient to continue to think about just how to resolve nutritional problems clinically and by research. We need to think about this problem more deeply than this. Without a global approach, we can’t resolve our nutritional problems, so if we need to use milk and meat for our children in developing countries, we need to improve family income. In parallel to research, in parallel to our medical practice we need to develop other strategies to take care of the real determinants of these nutritional problems. Without this approach we can’t improve the nutritional status of our children.

*Dr. Allen:* I see this is a sort of a hierarchy of alternatives, often using more than one together. For example, where a country could afford to provide school milk for children this would seem like a very good thing to do if the situation requires that the children be provided with better nutrition, and the economic argument would be that building human capital in this way is a very good investment for a country. The second level is perhaps providing the micronutrients in a much cheaper way. With the kind of milks that Dr. Michaelsen is talking about, that are much cheaper and governments could support and subsidize and could be produced locally. The third one is providing the micronutrients in a variety of different ways, and the fourth would just be a micronutrient supplement. These are a continuum of interventions. And food fortification, fortification of staples might provide most of these nutrients in a country where there are certain staples that are providing a large part of the children’s nutrients. So the right mix depends on the situation, and we don’t know all the answers. But certainly you can look at the nutrient intake of children and see which
nutrients are missing. There is never any substitute for getting some good food intake data and that is not that difficult, and then saying what the gaps are, and then how do we meet those by different strategies, starting with the most affordable and the most coverage for that kind of intervention.

Dr. Michaelsen: Some of the effects that you have shown could most likely also be seen after eating some underutilized animal foods like small fish, organs like intestines and kidneys, snails, as we have seen in the market here in Marrakesh, and insects, like mopane worms eaten in southern Africa. These underutilized foods are often cheap and should be promoted where culturally acceptable.

Dr. Allen: I think that’s true in theory, and the farmers will be very happy if you are eating all their insects. But when you figure out how much it probably takes, it’s probably not enough. I didn’t answer the question about liver. One of WHO’s recommendations is for young children to eat liver, because it’s one of the few ways you can get enough available iron and zinc. The trouble is, if you eat the amounts recommended to supply your needed iron and zinc, you are probably at toxic levels of vitamin A, and there are not enough chicken livers in the world. But in Guatemala, we see intestines and so on as the main source of meat for some poor families, and they do correlate at least with B12 status.

Dr. Ashish: Is the gut flora an important source of vitamin B12? The reason I am asking is that it is widely believed that our previous generations in India did not become significantly vitamin B12 deficient because there was an overgrowth of gut flora possibly due to poor quality drinking water, and as time goes by and water becomes more and more affordable we would have less amount of gut flora and vitamin B12 deficiency will become more obvious in the population. Do you have any comment on that?

Dr. Allen: I am familiar with the proponents of that theory, but I would maintain that really B12 status has always been an issue in populations with a low source of animal foods, and this is not a new phenomenon. I actually disbelieved completely this theory until actually Ranjan Yajnik talked about a study he had done. He measured the B12 on fruits and vegetables before and after they have been sitting on the counter a whole night and actually showed there was an increase, but still the amounts were extremely low and unlikely to support adequate nutrition. So, if you do those calculations, it doesn’t adapt to meeting even close to requirements.

Dr. Boukari: In this intervention study, have you looked at other micronutrients like zinc, and could you make some comments on the data on the zinc status in these populations?

Dr. Allen: In Kenya or Guatemala, we did not see an effect of any of the interventions on serum zinc. Serum zinc is very hard to shift. There were also a lot of infections, there was a high prevalence of malaria, and all of these things were possible confounders. Even though we corrected for C-reactive protein and all these things, there was still a tremendous amount of noise among children, and you could see it depended on whether they had malaria recently or not. So, we really haven’t seen any effects yet. I am not sure that any food intervention study has shown an improvement in serum zinc, I don’t think so. It’s hard enough with fortified flour to see the improvement. Supplements work, but there is only one study showing an effect of zinc fortification of flour on zinc status.

Dr. Boukari: Do you think zinc plays a role in infant nutrition?

Dr. Allen: Probably yes. Certainly, zinc deficiency is associated with stunting, but it has to be fairly severe deficiency and very low plasma zinc, and probably that’s why meat was more effective at restoring activity and muscle mass and so on than milk, but that’s a conjecture at this point.