The importance of milk and other animal-source foods for children in low-income countries

Daphna K. Dror and Lindsay H. Allen

Abstract

Background. *Milk and other animal-source foods are concentrated dietary sources of macro- and micronutrients. Despite a global increase in milk production and consumption over the past decades, milk and other animal-source foods are often lacking in the diets of children in developing countries.*

Objective. *To evaluate the importance of milk and other animal-source food intake in promoting the growth, development, and health of children in low-income countries.*

Methods. *Original research articles describing observational and intervention studies with unfortified milk, fortified milk, and other animal-source foods in children were identified by searching the PubMed database.*

Results. *Consumption of milk and other animal-source foods by undernourished children improves anthropometric indices and cognitive function and reduces the prevalence of biochemical and functional nutritional deficiencies, reducing morbidity and mortality. Unfortified and fortified milk used in supplementation trials has been well tolerated and widely accepted by parents and children.*

Conclusions. *To improve the dietary quality of children in low-income countries and further the effort to eradicate extreme poverty and hunger in accordance with the United Nations Millennium Development Goals, additional research is necessary to identify and implement programs and policy supporting increased intake of milk and other animal-source foods.*

Key words: Animal-source foods, children, developing country, growth, milk

The authors are affiliated with the USDA ARS Western Human Nutrition Research Center, Davis, California, USA.

Please direct queries to the corresponding author: Daphna Dror, Allen Laboratory, USDA ARS WHNRC, 430 W. Health Sciences Dr., Davis, CA 95616, USA; e-mail: dkdror@ucdavis.edu.

Introduction

The consumption of milk and other animal-source foods in low-income countries is often very limited. Animal-source foods provide less than 5% of total energy intake in many countries of sub-Saharan Africa, 5% to 10% in most other African countries and southern Asia, 10% to 15% in eastern and northern Asia and Mexico, and 20% and more in the United States, Canada, Europe, and Australasia [1]. Plant-based diets are high in phytate and fiber and are lower in energy density, provide poorer-quality protein, have low levels of absorbable iron and zinc, are devoid of vitamin B_{12}, and cause reduced bioavailability of calcium and other minerals [2–3].

Milk and meat differ in their micronutrient contents. Milk contains more vitamin B_{12}, vitamin A, riboflavin, folate, and calcium but is low in iron [4], and meat is a rich source of heme iron, zinc, riboflavin, and vitamin B_{12} (**table 1**) [5].

Vitamin B_{12} is found *only* in animal-source foods, explaining the high prevalence of deficiency in most developing countries [9]. Milk is a particularly important form of animal-source food, since it is intended for nurturing the young, a population group at high risk for nutritional deficiencies in many low-income countries. Milk promotes growth by providing energy, protein, and micronutrients and by stimulating growth factors.

Global prevalence of micronutrient deficiencies

Animal-source foods are a rich source of iron, vitamin A, zinc, and iodine, the micronutrients with the highest global prevalence of deficiency. A World Health Organization (WHO) review of nationally representative surveys from 1993 to 2005 indicates that 47% of preschoolchildren worldwide suffer from anemia. Iron deficiency, the main cause of which is low consumption of meat, poultry, and fish, is assumed to be the etiology of 50% of anemia cases globally and in

TABLE 1. Nutrient contents of 100 g of whole cow's milk and cooked beef compared with selected daily RDAs for children[a]

Nutrient	Cow's milk[b]	Beef[c]	Age group (yr)			
			1–3	4–8	9–13	14–18
Energy (kcal)	61	291	1,000	1,200–1,400	1,600 (F) 1,800 (M)	1,800 (F) 2,200 (M)
Protein (g)	3.2	26.4	13	19	34	52
Calcium (mg)	113	9	700	1,000	1,300	1,300
Vitamin B_{12} (μg)	0.45	2.47	0.9	1.2	1.8	2.4
Vitamin A (RAE)	46	0	300	400	600	700 (F) 900 (M)
Riboflavin (mg)	0.17	0.22	0.5	0.6	0.9	1.3
Folate (μg)	5	7	150	200	300	400
Iron (mg)	0.03	2.68	7	10	9	11 (F) 15 (M)
Zinc (mg)	0.37	6.0	3	5	8	9 (F) 11 (M)
Iodine (μg)	20	18	90	90	120	150

RAE, Retinol Activity Equivalent; RDA, Recommended Dietary Allowance
a. Nutrient contents except iodine are from USDA National Nutrient Database for Standard Reference [4]. Iodine values from Pennington et al. [6]. RDAs are from Food and Nutrition Board, Institute of Medicine [7–8].
b. Whole cow's milk, 3.25% milkfat, without added vitamin A and D, per 100 g [4].
c. Composite of trimmed retail cuts, separable lean and fat, trimmed to 1/8 inch fat, all grades, cooked, per 100 g [4].

malaria-endemic regions [10–11]. Vitamin A deficiency is a significant public health problem globally, with an estimated 33% of preschoolchildren deficient. In sub-Saharan Africa and South East Asia, more than 40% of preschoolchildren are vitamin A deficient [12]. Food sources of preformed vitamin A include milk, eggs, and liver. Zinc deficiency across subregions of the world is estimated to affect 5% to 79% of children under age five, with the highest prevalence in South Asia and Sub-Saharan Africa [13]. Meat and dairy products are good sources of zinc. Nationally representative data on urinary iodine collected worldwide between 1997 and 2006 suggest that 31.5% of school-age children have insufficient iodine intake, with the highest prevalence of insufficiency in Europe, the Eastern Mediterranean, and Africa [14]. Although the iodine concentration of milk varies widely depending on the iodine content of water and animal feed, season, and use of iodine as a disinfectant of udders and milking tools, studies in many countries have found that cow's milk is a relevant source of dietary iodine [15–21].

Important constituents of cow's milk for children

Among animal-source foods, milk is believed to play a unique role in promoting children's growth and development. Consumption of cow's milk is a relatively recent phenomenon that dates back to the beginning of animal domestication [22]. Given that milk is intended to support the growth and development of nursing mammals, it has been hypothesized that consumption of cow's milk during childhood will have a positive impact on linear growth [23]. This process may be driven by the energy or protein content, by specific micronutrients or their combination, or by other factors present in milk.

Milk is a rich source of energy and protein, providing 34 to 61 kcal (depending on fat content) and approximately 3.2 g of protein per 100 g [4]. In developing countries, where diets are often nutrient deficient, intake of animal-source foods, including milk, has stimulated linear growth and weight gain in infancy, childhood, and adolescence. Although energy and high-quality protein contribute to the stimulation of growth, evidence suggests that these effects are mediated by other factors present in milk [22, 24].

Milk supplies children with multiple micronutrients important for growth and development. Per 100 g, unfortified whole cow's milk provides 0.45 μg of vitamin B_{12}, 46 retinol activity equivalents (RAE) of vitamin A, 0.17 mg of riboflavin, 5 μg of folate, and 113 mg of calcium [4]. Low intakes of animal-source foods, including milk, were associated with inadequate vitamin and mineral intakes in a multicountry study of preschoolers aged 18 to 30 months in Egypt, Mexico, and Kenya [25–26].

Aside from alleviating some common micronutrient deficiencies, consumption of micronutrients from milk predicts weight and height gain. In Kenyan schoolchildren, both height and weight gain were positively predicted by average daily intakes of vitamin B_{12}, preformed vitamin A, and calcium provided in milk (or meat) supplements [27].

Calcium, including calcium from milk, has been associated with bone mineral accretion in children. In Hong Kong, 9- and 10-year-old children randomized to receive milk powder equivalent to 1,300 mg/day of calcium for 18 months had a significantly greater increase in total hip and spine bone mineral density (BMD) compared with controls, while those randomized to receive 650 mg/day of calcium had a significantly greater increase in whole body BMD compared with controls [28]. Other studies have also found an association between milk or calcium intake and bone mineralization in children and adolescents [29–33]. The misconception that calcium in milk impairs iron absorption is widespread in the scientific literature, arising from the results of single-meal studies conducted in the 1970s [34]. However, more recent multiple-meal and longer-term absorption studies show no significant effect of calcium intake on iron absorption or iron nutritional status in children or adults [35, 36].

In addition to macro- and micronutrients, an important attribute of cow's milk is that it stimulates growth factors. One of three ligands in the insulin-like growth factor (IGF) family of growth factors, IGF-1 is the most abundant in bone and facilitates growth by increasing uptake of amino acids, which are integrated into new proteins in bone tissue [37]. Although the results of intervention and observational studies in children are not entirely consistent and are lacking in developing countries, there is reasonable evidence that milk consumption increases circulating concentrations of IGF-1. A significant increase in serum IGF-1 was observed in 82 British girls aged 12 years consuming 1 pint (568 mL) of milk daily for 18 months after adjustment for pubertal status [30], and in 24 Danish boys aged 8 years consuming 1,500 mL of milk daily for 1 week [38]. IGF-1 was positively associated with milk or dairy intake in 521 British children 7 and 8 years of age [39] and in 90 Danish children aged 2.5 years [40], but not in 105 Danish children aged 9 months and subsequently aged 10 years [41]. Potential factors in milk that may stimulate IGFs, including IGF-1 and insulin, are casein, branched-chain amino acids, calcium, and zinc [22].

Linoleic acid (LA; n-6) and α-linolenic acid (ALA; n-3) are polyunsaturated fatty acids (PUFAs) essential for humans. Both are precursors for endogenous synthesis of long-chain polyunsaturated fatty acids (LC-PUFAs), which are components of cellular membranes in the nervous system and necessary for the synthesis of arachidonic acid (AA; n-6) and docosahexaenoic acid (DHA; n-3). Breastmilk and vegetable oils contain considerable amounts of PUFAs and LC-PUFAs, whereas cow's milk contains very small amounts of PUFAs and practically no LC-PUFAs [42]. However, the LA:ALA ratio of cow's milk is favorable and may actually promote tissue DHA synthesis [43]. One study comparing breastmilk, formula, and cow's milk fed to full-term infants found the highest levels of DHA in the breastfed group, but higher levels of DHA in the cow's milk than in the formula group [44].

Conjugated linoleic acid (CLA), a PUFA naturally synthesized from LA in ruminants, comprises 0.1% to 1.1% of ruminant animal fat and has been associated with decreased fat mass accretion when supplemented in young mice [45, 46]. Although intake from naturally occurring CLA in dairy and meat products is minimal, a double-blind, placebo-controlled trial supplementing overweight or obese children aged 6 to 10 years with 2.4 g/day of CLA in chocolate milk for 7 ± 0.5 months found a significant reduction in total, abdominal, and peripheral body fat percentage compared with controls [47].

Substitutes for cow's milk

In some developing countries, goats, sheep, or buffalo are more accessible as household livestock than cows. Cultural beliefs surrounding the nutritive and medicinal properties of milk produced by various mammals may make its consumption by children more or less desirable. In the Gursum community in Ethiopia, for example, goat's milk is highly valued and is often given to children as a supplement to breastmilk [48]. Except for its higher content of medium-chain fatty acids, the macronutrient composition of goat's milk is similar to that of cow's milk, and it has been used successfully as an alternative to cow's milk for short-term rehabilitation of undernourished children in Madagascar [49]. However, goat's milk is known to be deficient in folate and infants fed exclusively with goat's milk present with megaloblastic anemia of folate deficiency [50–52]. The milk of other mammals, including sheep and buffalo, is similar to but slightly higher in protein and fat content than cow's milk [4, 53].

Studies investigating the impact of milk and other animal-source foods in children's diets

To consider the impact of milk and other animal-source foods on growth, cognitive performance, micronutrient status, physical activity, and additional outcomes, original research articles describing observational and intervention studies were identified by searching the PubMed database. Search terms included "children," "preschool," "school," "milk," "meat," "fish," "egg," "animal source food," "fortified," "growth," "anemia," "intervention," and "supplementation." Inclusion criteria were broadly defined as observation of or intervention with unfortified or fortified milk, meat, or other animal-source foods in children less than 18 years of age. Studies were excluded if they were carried out in pregnant girls, hospitalized children, or populations selected for the presence of disease.

Observational studies

In general, there is little doubt that infants and young children who receive inadequate amounts of animal-source foods usually have poorer growth, cognitive performance, and motor function. Older studies of the adverse effects of macrobiotic diets on child development in The Netherlands are informative in this regard, because such diets were similar to or poorer than those of some children in developing countries. In addition, these studies had less confounding by illness caused by poor sanitation than would occur in developing countries. Compared with omnivorous controls, children consuming macrobiotic diets had significantly lower intakes of protein, fat, calcium, riboflavin, vitamin B_{12}, and vitamin C. Although birthweights were lower (3,290 vs. 3,470 g), growth was normal until 4 months, at which point it declined dramatically (13.2 cm/year compared with 16.7 cm/year in controls). Growth stabilized at 16 months, but there was no catch-up later [54]. Children from these families who consumed dairy products three times a week grew better than those who consumed them rarely. The macrobiotic infants had substantially higher prevalence rates of iron deficiency, riboflavin deficiency, vitamin B_{12} deficiency, anemia, and rickets [55]. Macrobiotic infants had delays in gross motor development and in speech and language development. In early adolescence, vitamin B_{12} status and cognitive function were still poorer than in controls, even though parents had heeded advice to feed animal-source foods, starting at the age of 6 years on average [56].

From analysis of Demographic and Health Survey data from seven countries in Latin America, milk intake was significantly associated with better length- and weight-for-age z-scores in all countries, whereas meat intake showed this association in only one country. However, it is possible that the range and amount of meat intake were inadequate to reveal any associations with usual consumption [57]. In rural Kenya, for example, there was no association between usual intake of animal-source foods, which was very low, and adequacy of micronutrient intake in schoolchildren until additional animal-source food was added to the diets (Allen et al., unpublished data). Usual intake of animal-source foods, expressed as percentage of total energy, was the main predictor of many outcomes in the observational Nutrition Collaborative Research Support Program (NCRSP) conducted in Egypt, Kenya, and Mexico during the 1980s, including child growth, affect, cognitive function, physical activity, and micronutrient status [58]. In an earlier study in Kenya, animal protein intake at 18 to 30 months of age was a stronger predictor of cognitive function 5 years later than was total protein intake, although associations with milk vs. meat were not analyzed separately [59]. Similar results were found among Egyptian children [60]. In Peru, linear growth between 12 and 15 months of age was positively associated with intake of animal-source foods in children with a low intake of complementary foods, but again there was no separation of milk and meat in the analysis [61]. In Nepal, children with high meat or fish intake at 13 to 24 months of age were significantly less likely to present with vitamin A deficiency–associated xerophthalmia at 1 to 6 years of age [62].

Intervention trials

A limited number of randomized, controlled intervention trials have been performed to determine the effects of adding animal-source foods to the diets of young children. An older review of the efficacy of different animal-source food interventions concluded that supplements containing at least some dried milk improved children's growth in 12 of 15 studies [63]. Outcomes usually measured include weight-for-age and height-for-age z-scores, micronutrient status, cognitive performance, and/or level of physical activity. The studies described here are presented by type of intervention design, in so far as possible (**tables 2** and **3**).

Interventions with milk, meat, or fish vs. a nonintervention or equicaloric control

Surprisingly few investigators in developing countries have fed milk to one group of children and compared the outcomes with those in a nonintervention or equicaloric control group. In the 1960s, the benefits of feeding 75 g of skim milk or 30 g margarine daily with a control diet were evaluated in New Guinea schoolchildren [64]. After 13 weeks, height increased by 2.3 cm in the milk group compared with 1.1 and 1.0 cm in the control and margarine groups.

A well-designed study was conducted in rural Kenya [84]. Equicaloric (≈ 250 kcal/day) supplementation of 544 children aged 5 to 14 years (median, 7.4 years) with traditional maize- and bean-based porridge (*githeri*) containing additional oil, meat, or milk over seven consecutive school terms (2.25 years) significantly increased weight gain compared with a nonsupplemented control group [85]. Milk supplementation had a significant effect on height gain in those children who were younger and already stunted, whereas meat did not improve height gain. In an analysis taking into account the total food intake of the children and controlling for sex, age, and socioeconomic status, growth was positively predicted by energy and nutrients provided in bioavailable forms from milk and meat. Both height and weight gain were positively predicted by average daily energy intake from animal-source foods, heme iron, preformed vitamin A, calcium, and vitamin B_{12}, whereas gain in muscle mass was predicted by average daily energy

TABLE 2. Interventions with milk or meat vs. nonsupplemented or equicaloric control group

Ref.	Location	No. of subjects	Age at entry	Intervention	Outcomes
[64]	New Guinea	88	5-15 yr	Daily for 13 wk I/II: 75 g skim milk or 30 g margarine + normal diet III: Normal diet (high in taro and sweet potato)	Significantly greater height gain in milk than in margarine or control groups. Greatest weight gain in milk group
[2, 65]	Embu District, Kenya	544	5–14 yr	7 school terms (2.25 yr) daily I: *Githeri* (maize and bean-based porridge) with finely ground beef II: *Githeri* with 1 glass UHT milk III: *Githeri* with added vegetable oil IV: Control (no supplement)	Significant increase in plasma vitamin B_{12} 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
Allen et al., unpublished data	Guatemala City	302	12 mo	9 mo, supervised feeding at 1 meal/day, 5 days/wk for 9 mo I: Ground beef (72 g, 102 kcal/day, providing 0.56 µg vitamin B_{12}) II: Fruit + vegetables (92 kcal/day, fortified with 0.86 µg vitamin B_{12}) III: Fruit + vegetables, unfortified (92 kcal/day)	No effects of beef or vitamin B_{12} fortification on any child outcomes in a vitamin B_{12}–deficient population Cow's milk intake from usual diet positively predicted vitamin B_{12} status, whereas breastmilk intake was a negative predictor
[66]	Mangochi District, Malawi	281	2.5–7.5 yr	12-mo dietary diversification strategy including: I: Increased consumption of animal-source foods (especially whole dried fish) and orange-red fruits II: Control (no intervention)	Significant improvement in MUAC z-score and reduced prevalence of inadequate vitamin B_{12}, calcium, and zinc intake postintervention Hemoglobin significantly higher, incidence of anemia and common infections significantly lower in intervention group than in control group
[67]	Periurban Lima, Peru	137	12–17.9 yr	9 mo I: Community-based, behavioral and dietary intervention to increase heme iron, total iron. and ascorbic acid intake II: Control (no intervention)	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
[68]	Ghana	672	6 mo	6 mo, daily. Weanimix made from maize, soy, peanuts I/II: Fermented maize or Weanimix + 20% whole fish powder III: Weanimix + MMN IV: Weanimix V: Cross-sectional nonintervention	No significant effects among intervention groups in weight or length gain, hematologic values, or iron, zinc, or riboflavin status Growth poorest in nonintervention group
[69]	Northern Cape Province, South Africa	183	7–9 yr	6 mo, school days only I: 25 g bread spread containing marine fish flour (892 mg DHA/wk) II: 25 g bread spread without fish flour	Significantly higher EPA and DHA levels and cognitive function (verbal learning ability and memory) test scores in experimental group than in control group
[38]	Frederiksberg, Denmark	24	8 yr	7 days I: 1,500 mL skim milk II: 250 g low-fat meat	Significant increase in IGF-1 and IGF-1:IGFBP-3 ratio in milk but not in meat group
[30]	Sheffield, UK	82	12.2 ± 0.3 yr	18 mo daily supplementation with 568 mL (1 pint) I: Whole or reduced fat milk II: Control	Significantly greater BMC, BMD, and plasma IGF-1 in milk group than in control group

BMC, bone mineral content; BMD, bone mineral density; EPA, eicosapentaenoic acid; DHA, docosahexaenoic acid; IGF-1, insulin-like growth factor 1; IGFBP-3, insulin-like growth factor binding protein-3; MMN, multiple micronutrients; MUAC, mid-upper-arm circumference; UHT, ultra-high temperature.

TABLE 3. Fortified milk supplementation trials in children

Ref.	Location	No. of subjects	Age at entry	Intervention	Outcomes
[70]	Mexico City, Mexico	227	8–60 mo	90 days supplementation with 500 mL fortified milk containing 22.5 mg zinc, 1.5 mg iron, 2,250 µg vitamin A, 105 mg vitamin C	Significant improvement in weight-for-height z-scores and in plasma levels of vitamin B_{12}, folic acid, and hemoglobin
[71]	Central and eastern Mexico	567	12–30 mo	12 mo daily I: 48 g fortified milk powder (5.3 mg iron, 5.3 mg zinc, 48 mg vitamin C), reconstituted to 400 mL II: 48 g unfortified milk powder (0.2 mg iron, 1.6 mg zinc, 6.8 mg vitamin C), reconstituted to 400 mL	Prevalence of moderate anemia (hemoglobin 90–100 g/L) and iron deficiency (serum ferritin < 12 µg/L) significantly lower in fortified-milk group at 6 and 12 mo (no other measures)
[72]	Puebla, Mexico	115	10–30 mo	6 mo daily I: 48 g fortified milk powder (5.3 mg iron, 5.3 mg zinc, 48 mg vitamin C), reconstituted to 400 mL II: 48 g unfortified milk powder (0.2 mg iron, 1.9 mg zinc, 6.8 mg vitamin C), reconstituted to 400 mL	Significant decline in prevalence of anemia (from 41.4% to 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)
[73, 74]	New Delhi, India	633	1–3 yr	1 yr daily I: MMN-fortified milk powder providing 9.6 mg zinc, 9.6 mg iron, 6.6 µg selenium, 0.3 mg copper, 330 µg vitamin A, 48.0 mg vitamin C, 8.1 mg vitamin E/day II: Unfortified milk powder	Fortified milk group had significantly reduced incidence Differences in morbidity most pronounced in children < 2 yr Significant improvement in weight and height gain, serum hemoglobin and ferritin, and risk of iron-deficiency anemia in fortified-milk group
[75]	Bac Ninh Province, Vietnam	454	7–8 yr	6 mo, school days only I: 500 mL unfortified milk II: 500 mL MMN-fortified milk providing 5.5 mg zinc, 6.5 mg iron, 6.7 µg vitamin A, 165 mg vitamin C, 13 mg vitamin E/day III: Control (no supplementation)	Weight-for-age and height-for-age z-scores improved significantly in both milk groups but not in control group 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 significantly with milk intervention
[76]	Dong Thap Province, Vietnam	1,080	6 yr	143 nonconsecutive days over 529-day period I: 200 mL vitamin A- and D-fortified milk + MMN-fortified biscuits, providing 424 µg vitamin A, 5 mg iron, and 6 mg zinc (300 kcal total) II: Control (no supplementation)	Small but significantly greater gains in weight and height in milk group compared with control over study period
[77]	North Island, New Zealand	172	6–8 yr	2 yr, school days only I: 300 mL fortified milk providing 1.5 µg vitamin D, 480 mg calcium, 165 µg vitamin A II: Control: no supplement	25(OH)D, HDL-C, and HDL-C:LDL-C ratio significantly higher in milk than in control group Mean 25(OH)D in milk group still below recommended 60 nmol/L

[78]	Malmö, Sweden	36	12 mo	6 mo daily I: Iron-fortified milk (7.9 or 14.9 mg/L), ad lib II: Control: unfortified milk, ad lib	Nearly significant increase in serum ferritin in fortified milk compared with control group Control group children consuming 500–600 mL milk/day were unable to meet recommended iron intake (8 mg/day)
[79]	Vicosa, Brazil	190	2–5 yr	101 class days I: 80 mL iron-fortified whole milk (3 mg iron) fermented with *Lactobacillus acidophilus* II: 80 mL iron-fortified unfermented whole milk (3 mg iron)	Significant positive correlation between iron intake and hemoglobin in fermented milk group Nonsignificantly greater increase in hemoglobin in fermented milk group Weight-for-age and height-for-age increased significantly in both groups
[32]	Beijing, China	757 girls	10 yr	2 yr, school days only I: 330 mL calcium-fortified milk (560 mg calcium) II: 330 mL calcium- + vitamin D-fortified milk (560 mg calcium, 5 or 8 μg vitamin D) III: Control (no supplementation)	Significant increase in change in height, sitting height, body weight, total size-adjusted BMC, and BMD in supplemented groups compared with control Significant increase in size-adjusted BMC and BMD in vitamin D + calcium group compared with calcium-only group
[80]	South Island, New Zealand	225	12–20 mo	20 wk daily I: Red meat dishes (2.6 mg iron/day) II: MMN-fortified milk powder (1.5 mg iron/100 g), ad lib III: Control: unfortified milk powder (0.01 mg iron/100 g), ad lib	Serum ferritin and body iron significantly higher in fortified milk group than in control group Serum ferritin significantly higher in red meat group than in control group
*	Jakarta and Solo, Indonesia	245	7–9 yr	6 mo daily I: Iron- and zinc-fortified milk II: Control: unfortified milk	Significant improvement in body weight and cognitive performance in group receiving fortified milk compared with control group No significant difference in hemoglobin or ferritin
[28]	Shatin region, Hong Kong	344	9–10 yr	18 mo daily I: 40 g calcium-enriched milk powder (200 kcal, 5 g protein, 650 mg calcium) II: 80 g calcium-enriched milk powder (400 kcal, 10 g protein, 1,300 mg calcium) III: Control (no supplementation)	Total hip and spine BMD showed significantly higher increase in 80-g milk group than in control group Total body BMD showed significantly higher increase in 40-g milk group than in control group
Iron-deficient or anemic children in wealthier populations					
[81]	Tupa, Brazil	185	6 mo–2 yr, 87% with mild or severe anemia	1 L/day iron-fortified whole cow's milk (3 mg iron) for 7.3 mo	Hemoglobin normalized in 57% of subjects following intervention Highest hemoglobin repletion rate in severely deficient group, no change in children with normal status initially

continued

TABLE 3. Fortified milk supplementation trials in children (*continued*)

Ref.	Location	No. of subjects	Age at entry	Intervention	Outcomes
[82]	Buenos Aires, Argentina	17	12–48 mo with mild iron deficiency 65% anemia	4 mo daily iron-fortified fluid cow's milk (15 mg iron/L), ad lib	100% of children achieved normal values for hematocrit, hemoglobin, serum iron, and transferrin saturation Changes in hematocrit and hemoglobin significantly greater in children anemic at study entry
[83]	Santiago, Chile	554	3 mo; % anemia or iron deficiency not stated	12 mo daily I: Full-fat fortified milk powder (15 mg iron, 100 mg vitamin C, 1,500 IU vitamin A, 400 IU vitamin D/100 g) acidified with *Streptococcus lactis*, prepared as 10% dilution, ad lib II: Full-fat nonacidified unfortified milk powder, prepared as 10% dilution, ad lib	At ages 9 and 15 mo, all measures of iron status (hemoglobin, serum iron, total iron-binding capacity, transferrin saturation, free erythrocyte protoporphyrin, and serum ferritin) significantly higher in fortified-milk group than in control group

BMC, bone mineral content; BMD, bone mineral density; HDL-C, high-density-lipoprotein cholesterol; LDL-C, low-density-lipoprotein cholesterol; MMN, multiple micronutrients; 25(OH)D, 25-hydroxy vitamin D

intake from animal-source foods and vitamin B_{12} [27]. Children in the meat, energy, and milk groups gained significantly more mid-upper-arm circumference (0.33, 0.27, and 0.19 cm, respectively) than did children in the control group. Mid-upper-arm muscle area increased significantly more in the meat group than in the milk and energy groups, and moderately more in the milk and energy groups than in the control group [85].

Plasma vitamin B_{12} increased significantly in both the milk and meat intervention groups; the prevalence of combined severe and moderate deficiency (plasma vitamin B_{12} < 221 pmol/L) after 2 years of intervention fell from 80.7% to 64.1% in the meat group and from 71.6% to 45.1% in the milk group, but did not fall in the control group [65]. No improvement was found in the status of other micronutrients in the same intervention groups, although changes may have been obscured by malaria and other infections [5].

An intervention study in Guatemala investigated the feasibility and efficacy of supervised equicaloric supplementation of children with meat vs. fruit and vegetables containing added vitamin B_{12}, vs. fruit and vegetables alone, 5 days a week from 12 months of age. At the end of the 9-month intervention, there were no significant differences among the groups in growth, hemoglobin, ferritin, or plasma vitamin B_{12}, cognitive or motor function, or any of several other measures of child development. At baseline (12 months of age) and postintervention, vitamin B_{12} deficiency was associated with poorer cognitive function and slower motor development, with the same children tending to be vitamin B_{12} deficient at the beginning and end of the intervention. Breastmilk at 12 months postpartum was seriously inadequate in vitamin B_{12}, with none detectable in about half of the samples. The infants' usual intake of cow's milk—usually reconstituted, unfortified dried milk—was a positive predictor of their vitamin B_{12} status, whereas breastmilk intake was a negative predictor (Allen et al., unpublished data). Cow's milk has approximately 10-fold more vitamin B_{12} per kilocalorie than breastmilk of well-nourished women, and substantially more vitamin B_{12} than breastmilk of women consuming low amounts of animal-source foods. In the Kenyan trial that provided meat or milk to schoolchildren over a 2-year period, vitamin B_{12} status was significantly improved but still did not reach normal values in many children [65], revealing that vitamin B_{12} repletion takes a considerable amount of time once stores are depleted.

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 fermented maize or a cereal-legume blend produced for complementary feeding in Ghana did not improve growth or micronutrient status compared with an unfortified group [68]. South African children aged 7 to 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 on cognitive function. There were significant increases in eicosapentaenoic and docosahexaenoic acid concentrations in the intervention group and improved performance on learning and reading tests [69].

Dietary diversification and modification strategies have attempted to increase consumption of animal-source foods. A 12-month intervention designed to increase intake of animal-source foods (especially dried fish with bones) and reduce dietary phytate in Malawian children aged 2.5 to 7.5 years significantly improved z-scores for mid-upper-arm circumference and arm muscle area. 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 the insufficient duration of the intervention, the age range of the children, or intergenerational effects of malnutrition. However, the intervention reduced the prevalence of inadequate intakes of vitamin B_{12}, calcium, and bioavailable zinc. Additionally, mean hemoglobin was significantly higher and the incidence of anemia was lower in the intervention group than in the control group [66]. A community-based, randomized behavioral and dietary intervention trial conducted in Peruvian adolescent girls encouraged animal-source food intake with the goal of improving iron status. Heme iron and ascorbic intakes increased significantly in the intervention group. Although the intervention was not sufficient to improve hemoglobin or iron status, it prevented the fall in these indicators observed in the control group [67].

Interventions with micronutrient-fortified cow's milk

In recognition of the fact that cow's milk is lacking in some micronutrients but is a relatively affordable, nutritious, 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. Given that bovine milk is known to be especially low in iron, most attention has been paid to improving its iron content.

Daily consumption of 500 mL of multimicronutrient-fortified whole milk for 90 days by 227 children aged 8 to 60 months in Mexico City significantly improved weight-for-height z-scores and plasma levels of vitamin B_{12}, folic acid, and hemoglobin. Per 500 mL, the fortified milk provided 1.5 mg of iron, 3 µg of vitamin B_{12}, 2 mg of folic acid, and 22.5 mg of zinc, in addition to other micronutrients. There was no control group. The fortified milk was well tolerated and widely accepted [70]. A significant reduction in anemia prevalence from 41% to 12% resulted when Mexican children aged 12 to 30 months were given 48 g of milk powder reconstituted to 400 mL and fortified with 5.3 mg of iron, 5.3 mg of zinc, and 48 mg of vitamin C, daily for 6 months. The control group received unfortified milk and showed no reduction in anemia [72].

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/day. Although it is not possible to separate the effects of individual nutrients or other program interventions on outcomes, the provision of micronutrient-fortified vs. unfortified milk caused significantly greater reductions in the prevalence of anemia and iron deficiency [71]. Participation in the milk program did not increase the prevalence of obesity in children [86].

In a periurban area of northern India, 633 children aged 1 to 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 of iron, 2.7 µg of vitamin B_{12}, 9.6 mg of zinc, and 330 µg of 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 the differences were most pronounced in children under the age of 2 years. Children in the treatment group had significant improvements in weight and height gain, mean serum hemoglobin and ferritin, and risk of iron-deficiency anemia compared with controls. Fortified milk was well accepted by the study population [73, 74].

In a similar trial in northern Vietnam, children aged 7 and 8 years in two schools were randomly assigned to receive 500 mL of ultra-high-temperature-treated, multimicronutrient-fortified or -unfortified milk 6 days per week for 6 months, while children in a third school served as controls. A total of 454 children participated in the trial. The micronutrient-fortified milk provided 6.5 mg of iron, 5.5 mg of zinc, 6.7 µg of vitamin A, 165 mg of vitamin C, and 13 mg of vitamin E per day. Weight-for-age and height-for-age z-scores improved significantly in both the fortified- and unfortified-milk intervention groups but not in the control group. Short-term memory scores were significantly higher in children in both milk groups compared with controls, with superior scores in the fortified-milk group. Parent-reported health-related quality of life improved significantly with both fortified- and unfortified-milk interventions [75].

In urban poor areas of Jakarta and Solo, Indonesia, 245 underweight children aged 7 to 9 years were randomly assigned to receive iron-zinc-fortified (n = 121) or -unfortified (n = 124) milk daily for 6 months. Body weight and cognitive performance showed significantly greater improvement in the group receiving fortified milk, although there was no difference in physical capacity or change in serum ferritin, hemoglobin, or zinc between groups.*

Iron-fortified cow's milk also improves the iron status of iron-deficient and/or anemic children in wealthier populations. In 225 nonanemic 12- to 20-month-old children in New Zealand randomly assigned to consume red meat, iron-fortified cow's milk, or nonfortified cow's milk daily for 20 weeks, serum ferritin and body iron were significantly higher in the fortified-milk group than in the control group [80]. In a study of 17 mildly iron-deficient Argentinean children aged 12 to 48 months, mothers were instructed to replace regular cow's milk with an iron-fortified fluid whole cow's milk containing 15 mg of iron per liter. After 4 months of intervention with an average daily milk intake of 877 ± 310 mL, all children achieved normal values of hematocrit, hemoglobin, serum iron, and transferrin saturation. There were no problems with tolerance or acceptance of the fortified milk [82]. 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 the fortified milks [83, 87, 88].

Interventions with modified-fat cow's milk

Although the notion of altering the fatty acid composition of cow's milk to optimize the benefits of its consumption on human health is within the scope of dairy biotechnology [89], few studies (none in developing countries) have investigated the effects of fat alteration on plasma PUFA, DHA, and AA in children. In Sweden, 38 children were assigned to one of four feeding groups at 12 months: low-fat milk, whole milk, 50% vegetable fat milk (rapeseed oil), or 100% vegetable fat milk (palm, coconut, and soy oils). After 3 months of ad libitum milk consumption, plasma PUFA levels were significantly higher in children consuming milks with vegetable fat than in those consuming whole milk. The percentage of LA in plasma triglycerides, phospholipids, and cholesterol esters was significantly greater in the 100% vegetable fat group than in the other groups, while the percentage of ALA was highest in the 50% vegetable fat group [90]. DHA and AA in lipid fractions did not differ significantly between groups, possibly because of compensation by endogenous synthesis or redistribution from other body compartments [42].

* Bardosono SL, Endang D, Sukmaniah S, Permadhi, Inge A, Andayani, Diyah E, Lestarina, L. Reduction of underweight prevalence and improvement of speed processing after a six month iron-zinc fortified milk supplementation among underweight pre-adolescent Indonesian children. 19th International Congress of Nutrition, Bangkok, Thailand, 2009.

Concerns about early introduction of cow's milk and children's health

Introduction of milk before the age of 12 months

According to WHO global public health guidelines, exclusive breastfeeding is recommended for the first 6 months of life. Thereafter, it is recommended that infants receive nutritionally adequate and safe complementary foods to meet their evolving nutritional needs, while breastfeeding is continued up to or beyond 2 years of age [91]. In most countries, including the United States, introduction of unmodified cow's milk is discouraged until after the first year of life because of concerns about nutrient imbalances and potential adverse effects on infant health.

Compared with breastmilk, cow's milk contains higher levels of protein, sodium, potassium, phosphorus, and calcium and insufficient levels of iron, vitamin C, and linoleic acid [92]. These differences result from the distinct needs of human and bovine young and are affected to a lesser extent by maternal nutritional status [93, 94]. Early introduction of cow's milk and other liquids is associated with a reduced duration and frequency of breastfeeding [95]. Exclusive breastfeeding has been shown to reduce morbidity and mortality in developing countries [96]. Furthermore, breastmilk contains indigestible human milk oligosaccharides (HMOs) that are believed to act as growth factors in establishing a stable gut microbiota to hinder pathogen colonization in the infant gastrointestinal tract [97, 98].

Introduction of cow's milk before 1 year may compromise iron nutrition both directly through low iron content and indirectly through occult blood loss and inhibition of iron absorption. Occult intestinal blood loss is estimated to occur in 40% of normal infants under 12 months of age during feeding of cow's milk [99]. However, studies measuring occult fecal blood and iron status in milk- and formula-fed infants over the past several decades have yielded largely inconsistent results, in part because of different ages of introduction of cow's milk [100–103]. It has been proposed that intestinal bleeding in early infancy may be related to the antigenic challenge of cow's milk to the gut mucosa before adequate development of oral immune tolerance to ingested foreign proteins [104].

Compared with breastmilk, cow's milk has a high renal solute load as a consequence of its higher protein and mineral contents. Immaturity of the renal system in the ability to concentrate urine, in conjunction with low fluid intake or extrarenal water losses, can lead to severe dehydration in young infants fed cow's milk [99].

The higher protein content of cow's milk-based formulas compared with breastmilk may influence metabolic rate and body composition in infancy and later in life. A meta-analysis of observational studies suggested that breastfed infants had a 20% lower odds of obesity when they reached school age than formula-fed infants, after adjustment for biological and sociodemographic confounding factors. This analysis included formulas that were not milk based, and the authors hypothesized that differences in obesity risk were due in part to the higher protein content of standard infant formulas compared with breastmilk [105]. A multicenter European randomized, controlled trial found that weight-for-length z-scores at 24 months of age were significantly lower in infants who were breastfed or received formulas with lower protein content (1.8 or 2.2 g/ 100 kcal) than in infants who received formulas with higher protein content (2.9 or 4.4 g/100 kcal) [106]. However, a study comparing breastfed infants with those fed a low-protein (1.8 g/100 kcal) or high-protein (2.7 g/100 kcal) formula found no differences in fat mass between groups at 6 months or 1 year of age.* Other studies have also failed to find an association between dietary protein intake in early life and later risk of obesity [41, 107]. Nevertheless, formula manufacturers have made available products with reduced protein content. It is unlikely that later introduction of cow's milk, especially in undernourished children with an overall lower protein intake, would increase the risk of later obesity, and it did not do so in the Mexican milk program [86].

Allergy

Children are the age group most frequently affected by cow's milk allergy, an IgE- or non-IgE (cellular)-mediated immune reaction to milk proteins. Although symptoms of milk allergy, including itching, skin rashes, edema, vomiting, diarrhea, and abdominal cramps, may be seen in 5% to 15% of infants, the global incidence according to strict diagnostic criteria is estimated to be 2% to 5% [108]. Often assumed to be a condition found only in Western countries, recent research suggests that a similar prevalence of milk allergy in developed countries is obscured by lack of awareness and diagnostic facilities [109]. Childhood IgE-mediated milk protein allergy resolves in approximately 80% of children by 3 years of age, whereas the resolution of cellular-mediated allergy depends on the pathophysiology of the inflammation [108]. Because milk elimination diets in children have been associated with growth retardation, kwashiorkor, hypocalcemia, and rickets [110], it is recommended that they be implemented only when medically indicated.

Milk, fortified milk, and other animal-source food interventions to improve the nutritional status of children

In 2001, the World Health Assembly urged the promotion of exclusive breastfeeding for 6 months as a global public health recommendation [111]. After 6 months of age, breastmilk alone is no longer sufficient to meet the nutritional requirements of the infant, and initiation of complementary feeding is encouraged in combination with continued breastfeeding. The idea that milk, both human and animal, supports the nutritional needs of children for growth and development is widespread. Introduction of unmodified cow's milk is not recommended until after the first year of life. Trials involving supplementation of infants and children over 12 months of age with regular or fortified cow's milk have demonstrated high rates of acceptance among parents and subjects [73, 82, 83].

There could be concern that using fortified milk to improve the nutritional status of children worldwide may be problematic because of the high global prevalence of lactose intolerance and milk allergy. Absorption of lactose, a disaccharide present in mammalian milk, requires the activity of lactase in the small intestinal brush border. Primary lactase deficiency refers to an insufficiency or absence of lactase and is the most common cause of lactose intolerance [112]. It has been estimated that approximately 70% of the world adult population is lactose intolerant to some extent, with higher prevalence (> 90%) among Southeast Asians and considerably lower prevalence (< 15%) among northern Europeans [113]. Although the global prevalence of lactose intolerance in children has not been estimated, it is expected to be lower, given that most lactase-deficient individuals experience symptom onset in late adolescence or early adulthood [112]. Cow's milk protein allergy, in contrast, is typically reported within the first 1 to 3 months of life and is estimated to occur in 2% to 5% of infants. However, most cases of cow's milk protein hypersensitivity resolve by 1 to 3 years of age [108, 114]. In milk supplementation trials conducted in children in different parts of the world (**tables 2** and **3**), reported intolerance of the supplement occurred in under 5% of the study population.

In developing countries, dairy supplements provided in powdered form require reconstitution with water, which may be a source of bacterial contamination. Since contaminated weaning foods are a major risk factor for diarrheal disease among children under 5 years of age [115], maternal education to ensure utilization of safe water for milk powder rehydration is critical for the success of any intervention program.

The stability of milk powder is another key issue defining its usefulness in public health interventions. The US industry standard for shelf life of whole milk powder is 6 to 9 months when stored at < 27°C and

* Labaune JM, Conus N, Mace K, Delmas P, Picaud JC, Vallet-Sandre Blandine B, Stenhout P, Putet G. Growth and body composition of infants breastfed or formula-fed with different protein levels during the first year. European Society of Pediatric Endocrinology, Istanbul, Turkey 2009.

< 65% relative humidity [116]. Replacement of milk fat with vegetable oil reduces cost while maintaining the macro- and micronutrient composition of the product. Skim milk powder, though less energy dense, remains a good source of high-quality animal protein (36 g/100 g) and has an average shelf life of 3 years [117]. Airtight, opaque packaging is imperative to optimize the stability of naturally occurring and added micronutrients and fatty acids [118].

Several trials have considered alternative means of increasing childhood consumption of milk and other animal-source foods in developing countries, either through offering dairy or meat livestock to families or through nutribusinesses. Several international humanitarian aid organizations, including Heifer International and FARM Africa, have successfully provided women with dairy animals through microfinance initiatives. In Ethiopia, evaluation of a dairy goat development project that provided two female goats to women heads of household demonstrated that the intervention increased milk intake by 109% and meat intake by 44% over 3 years. Furthermore, participants in the goat repayment program were able to generate steady annual income from sales of goats, allowing acquisition of additional resources and further supporting the availability of animal-source foods [48]. Other innovative approaches, such as solar-drying meat and vegetable mixtures, can increase meat consumption by young children [119].

Economic considerations

The potential economic benefits of animal-source food interventions for children have not been estimated directly but can be approximated in terms of costs averted. Disability-adjusted life years (DALYs) are used to quantify the loss of years of "healthy" life due to a particular cause and are calculated as the sum of years lost due to premature mortality and disability. Globally, it is estimated that 1.3%, 1.5%, 1.0%, and 0.2% of DALYs lost in children under 5 years of age are due to iron, vitamin A, zinc, and iodine deficiency, respectively [120]. There is an estimated 4% loss in future productivity of children whose cognitive development is impaired by anemia [121]. A review of the cost-effectiveness of micronutrient fortification concluded that fortification with iron, vitamin A, zinc, and iodine averts significant numbers of infant and child deaths in developing countries at relatively low cost [122].

In 2005, it was estimated that among children under 5 years of age, 20% in low- and middle-income countries were underweight, 32% in all developing countries were stunted, and 10% globally were wasted [123]. Undernutrition is directly or indirectly associated with approximately 60% of child mortality worldwide, with mild underweight nearly doubling the risk of death in childhood [124]. An estimated 18.7% of all DALYs lost among children under 5 years of age are due to underweight [120], which could be reduced by feeding animal-source foods in some situations.

Nutrition is thought to have the greatest effect on health, growth, and development when children are under 2 years of age [124]. Nutritional improvements in young children can lead to increases in the rate of school initiation and years of schooling, affecting wages and economic productivity in adulthood [125]. A meta-analysis of five cohort studies found small birth size and early childhood stunting to be linked with short adult stature [126]. A 1% decrease in adult stature is associated with a 1.4% decrease in productivity, and a 1% increase in adult stature is associated with an increase of 2.0% to 2.4% in wages or earnings [13].

These considerations suggest that reducing micronutrient deficiencies, underweight, and stunting by providing animal-source foods, and especially milk, to children can be very cost-effective, possibly more so if the milk is fortified with nutrients such as iron. However, specific cost–benefit estimates need to be developed in the context of economic and environmental conditions as well as local and national resources.

From 1964–66 to 1997–99, global milk consumption increased from 73.9 to 78.1 kg/year/person. In developing countries, the increase was much more dramatic: 28.0 kg/year/person in the earlier period to 44.6 kg/year/person in the later period, driven strongly by increased milk consumption in South Asia and Latin America [127]. For example, per capita milk supply increased from 38.4 to 85.9 kg/year/person from 1980 to 2007 in India and from 85.9 to 124.6 kg/year/person during the same period in Brazil [128].

The higher consumption of dairy products is largely attributed to greater production as well as per capita income growth in developing countries [129]. Between 1980 and 2003, global total dairy production increased from 475 to 626 million MT annually, with developing countries more than doubling production. Per capita milk supply in 2003 was estimated to be 82.5 kg/year globally and 49.3 kg/year in developing countries [113]. An increase in per capita income and the emergence of an affluent middle class in low- and middle-income countries over the past decades has contributed to rising net consumption trends, with demand for dairy products in these populations being highly income elastic. Other factors affecting dairy consumption in developing countries include urbanization and westernization of the diet [129]. Overall, these data imply that milk availability for children is improving on a global basis.

Conclusions

Animal-source foods and milk in particular are important but often lacking in the diets of children in low-income countries. Demonstrated benefits of animal-source food consumption by children include improved growth, micronutrient status, cognitive performance, and level of physical activity. Milk supplies essential macronutrients, micronutrients, fatty acids, and growth factors required for appropriate development throughout childhood. Despite an increase in global milk production and consumption, undernutrition and micronutrient deficiencies that could be alleviated by increased intake of milk and other animal-source foods remain highly prevalent among children under 5 years of age.

A review of the literature revealed that among undernourished children in developing countries, both milk and meat intake improved growth indicators, micronutrient status, and cognitive performance, with fortified milk superior to unfortified milk in reducing the prevalence of anemia. Improvement in iron status was also achieved by fortified-milk interventions among iron-deficient or anemic children in developed countries. Interventions with milk and fortified milk were culturally acceptable and well tolerated across study populations.

To improve the dietary quality of children in low-income countries and further the effort to eradicate extreme poverty and hunger in accordance with the United Nations Millennium Development Goals, additional research is necessary to identify and implement programs and policy supporting increased intake of milk and other animal-source foods. Studies to date have been limited to a single setting and have utilized widely varied types, frequencies, and durations of intervention. To better evaluate the feasibility and cost-effectiveness of potential programs aimed at increasing intake of milk, fortified milk, or other animal-source foods, well-designed multicenter studies are needed to compare alternative strategies longitudinally. Strategies to be included in research efforts and potentially future policy include school- or home-based supplementation programs, microfinance initiatives to increase local animal-source food production, and dietary modification programs.

References

1. Allen LH. Causes of nutrition-related public health problems of preschool children: available diet. J Pediatr Gastroenterol Nutr 2006;43 Suppl 3:S8–12.
2. Neumann CG, Murphy SP, Gewa C, Grillenberger M, Bwibo NO. Meat supplementation improves growth, cognitive, and behavioral outcomes in Kenyan children. J Nutr 2007;137:1119–23.
3. Murphy SP, Allen LH. Nutritional importance of animal source foods. J Nutr 2003;133:3932S–35S.
4. USDA. National nutrient database for standard reference. Available at: http://www.nal.usda.gov/fnic/foodcomp/search/ Accessed 1/20/2010.
5. Siekmann JH, Allen LH, Bwibo NO, Demment MW, Murphy SP, Neumann CG. Kenyan school children have multiple micronutrient deficiencies, but increased plasma vitamin B-12 is the only detectable micronutrient response to meat or milk supplementation. J Nutr 2003;133:3972S–80S.
6. Pennington JAT, Schoen SA, Salmon GD, Young B, Johnson RD, Marts RW. Composition of core foods of the U.S. food supply, 1982–1991. III. Copper, manganese, selenium, iodine. J Food Comp Anal 1995;8:171–217.
7. Food and Nutrition Board IOM. Dietary Reference Intakes (DRIs): Recommended Dietary Allowances and Adequate Intakes for Vitamins and Elements. National Academies Press; 2010.
8. Food and Nutrition Board IOM. Dietary Reference Intakes: Macronutrients. National Academies Press; 2005.
9. Stabler SP, Allen RH. Vitamin B12 deficiency as a worldwide problem. Annu Rev Nutr 2004;24:299–326.
10. de Benoist B, McLean E, Egli I, Cogswell M. Worldwide prevalence of anaemia 1993–2005. Geneva: World Health Organization, 2008.
11. Lynch SR. Why nutritional iron deficiency persists as a worldwide problem. J Nutr 2011;141:763S–8S.
12. Global prevalence of vitamin A deficiency (1995–2005). Geneva: World Health Organization, 2009.
13. Caulfield LE, Richard SA, Rivera JA, Musgrove P, Black RE. Stunting, wasting, and micronutrient deficiency disorders. In: Jamison DT, Breman JG, Measham AR, Alleyne G, Claeson M, Evans DB, et al., eds. Disease control priorities in developing countries (2nd ed.). Washington D.C.: World Bank; 2006: 551–68.
14. de Benoist B, McLean E, Andersson M, Rogers L. Iodine deficiency in 2007: global progress since 2003. Food Nutr Bull 2008;29:195–202.
15. Lamand M, Tressol JC. Contribution of milk to iodine intake in France. Biol Trace Elem Res 1992;32:245–51.
16. Dahl L, Opsahl JA, Meltzer HM, Julshamn K. Iodine concentration in Norwegian milk and dairy products. Br J Nutr 2003;90:679–85.
17. Cardenas Quintana H, Gomez Bravo C, Pretell EA. [Iodine content of cattle milk from mountain and coast from Peru]. Arch Latinoam Nutr 2003;53:408–12.
18. Borucki Castro SI, Berthiaume R, Laffey P, Fouquet A, Beraldin F, Robichaud A, Lacasse P. Iodine concentration in milk sampled from Canadian farms. J Food Prot 2010;73:1658–63.
19. Soriguer F, Gutierrez-Repiso C, Gonzalez-Romero S, Olveira G, Garriga MJ, Velasco I, Santiago P, de Escobar GM, Garcia-Fuentes E. Iodine concentration in cow's milk and its relation with urinary iodine concentrations in the population. Clin Nutr 2011;30:44–8.
20. Pennington JA. A review of iodine toxicity reports. J Am Diet Assoc 1990;90:1571–81.
21. Girelli ME, Coin P, Mian C, Nacamulli D, Zambonin

L, Piccolo M, Vianello-Dri A, Gottardo F, Busnardo B. Milk represents an important source of iodine in schoolchildren of the Veneto region, Italy. J Endocrinol Invest 2004;27:709–13.
22. Hoppe C, Molgaard C, Michaelsen KF. Cow's milk and linear growth in industrialized and developing countries. Annu Rev Nutr 2006;26:131–73.
23. Bogin B. Milk and human development: an essay on the "milk hypothesis." Antropologia Portuguesa 1998;15:23–36.
24. Berkey CS, Colditz GA, Rockett HR, Frazier AL, Willett WC. Dairy consumption and female height growth: prospective cohort study. Cancer Epidemiol Biomarkers Prev 2009;18:1881–7.
25. Murphy SP, Beaton GH, Calloway DH. Estimated mineral intakes of toddlers: predicted prevalence of inadequacy in village populations in Egypt, Kenya, and Mexico. Am J Clin Nutr 1992;56:565–72.
26. Calloway DH, Murphy SP, Beaton GH, Lein D. Estimated vitamin intakes of toddlers: predicted prevalence of inadequacy in village populations in Egypt, Kenya, and Mexico. Am J Clin Nutr 1993;58:376–84.
27. Grillenberger M, Neumann CG, Murphy SP, Bwibo NO, Weiss RE, Jiang L, Hautvast JG, West CE. Intake of micronutrients high in animal-source foods is associated with better growth in rural Kenyan school children. Br J Nutr 2006;95:379–90.
28. Lau EM, Lynn H, Chan YH, Lau W, Woo J. Benefits of milk powder supplementation on bone accretion in Chinese children. Osteoporos Int 2004;15:654–8.
29. Bonjour JP, Carrie AL, Ferrari S, Clavien H, Slosman D, Theintz G, Rizzoli R. Calcium-enriched foods and bone mass growth in prepubertal girls: a randomized, double-blind, placebo-controlled trial. J Clin Invest 1997;99:1287–94.
30. Cadogan J, Eastell R, Jones N, Barker ME. Milk intake and bone mineral acquisition in adolescent girls: randomised, controlled intervention trial. BMJ 1997;315:1255–60.
31. Dibba B, Prentice A, Ceesay M, Stirling DM, Cole TJ, Poskitt EM. Effect of calcium supplementation on bone mineral accretion in Gambian children accustomed to a low-calcium diet. Am J Clin Nutr 2000;71:544–9.
32. Du X, Zhu K, Trube A, Zhang Q, Ma G, Hu X, Fraser DR, Greenfield H. School-milk intervention trial enhances growth and bone mineral accretion in Chinese girls aged 10–12 years in Beijing. Br J Nutr 2004;92:159–68.
33. Merrilees MJ, Smart EJ, Gilchrist NL, Frampton C, Turner JG, Hooke E, March RL, Maguire P. Effects of diary food supplements on bone mineral density in teenage girls. Eur J Nutr 2000;39:256–62.
34. Monsen ER, Cook JD. Food iron absorption in human subjects. IV. The effects of calcium and phosphate salts on the absorption of nonheme iron. Am J Clin Nutr 1976;29:1142–8.
35. Harris SS. The effect of calcium consumption on iron absorption and iron status. Nutr Clin Care 2002;5:231–5.
36. Lynch SR. The effect of calcium on iron absorption. Nutr Res Rev 2000;13:141–58.
37. Cameron N. Human Growth and Development. New York: Academic Press; 2002.
38. Hoppe C, Molgaard C, Juul A, Michaelsen KF. High intakes of skimmed milk, but not meat, increase serum IGF-I and IGFBP-3 in eight-year-old boys. Eur J Clin Nutr 2004;58:1211–6.
39. Rogers I, Emmett P, Gunnell D, Dunger D, Holly J. Milk as a food for growth? The insulin-like growth factors link. Public Health Nutr 2006;9:359–68.
40. Hoppe C, Udam TR, Lauritzen L, Molgaard C, Juul A, Michaelsen KF. Animal protein intake, serum insulin-like growth factor I, and growth in healthy 2.5-y-old Danish children. Am J Clin Nutr 2004;80:447–52.
41. Hoppe C, Molgaard C, Thomsen BL, Juul A, Michaelsen KF. Protein intake at 9 mo of age is associated with body size but not with body fat in 10-y-old Danish children. Am J Clin Nutr 2004;79:494–501.
42. Svahn JC, Feldl F, Raiha NC, Koletzko B, Axelsson IE. Different quantities and quality of fat in milk products given to young children: effects on long chain polyunsaturated fatty acids and trans fatty acids in plasma. Acta Paediatr 2002;91:20–9.
43. Michaelsen KF, Hoppe C, Lauritzen L, Molgaard C. Whole cow's milk: why, what and when? Nestle Nutr Workshop Ser Pediatr Program 2007;60:201–16; discussion 16–9.
44. Courage ML, McCloy UR, Herzberg GR, Andrews WL, Simmons BS, McDonald AC, Mercer CN, Friel JK. Visual acuity development and fatty acid composition of erythrocytes in full-term infants fed breast milk, commercial formula, or evaporated milk. J Dev Behav Pediatr 1998;19:9–17.
45. Dhiman TR, Nam SH, Ure AL. Factors affecting conjugated linoleic acid content in milk and meat. Crit Rev Food Sci Nutr 2005;45:463–82.
46. Prais Botelho A, Santos-Zago LF, Costa de Oliveira A. Conjugated linoleic acid supplementation modified the body composition and serum leptin levels in weaning rats. Arch Latinoam Nutr 2008;58:156–63.
47. Racine NM, Watras AC, Carrel AL, Allen DB, McVean JJ, Clark RR, O'Brien AR, O'Shea M, Scott CE, Schoeller DA. Effect of conjugated linoleic acid on body fat accretion in overweight or obese children. Am J Clin Nutr 2010;91:1157–64.
48. Ayele Z, Peacock C. Improving access to and consumption of animal source foods in rural households: the experiences of a women-focused goat development program in the highlands of Ethiopia. J Nutr 2003;133:3981S–86S.
49. Razafindrakoto O, Ravelomanana N, Rasolofo A, Rakotoarimanana RD, Gourgue P, Coquin P, Briend A, Desjeux JF. Goat's milk as a substitute for cow's milk in undernourished children: a randomized double-blind clinical trial. Pediatrics 1994;94:65–9.
50. Davidson GP, Townley RR. Structural and functional abnormalities of the small intestine due to nutritional folic acid deficiency in infancy. J Pediatr 1977;90:590–4.
51. Naiman JL, Oski FA. The folic acid content of milk: revised figures based on an improved assay method. Pediatrics 1964;34:274–6.
52. Soltyski J, Krzemien G, Fracka B. [A case of megaloblastic anemia in an 11-month-old infant fed with goat milk]. Pediatr Pol 1996;71:709–11.
53. Hinrichs J. Mediterranean milk and milk products. Eur J Nutr 2004;43 Suppl 1:I/12–17.
54. Dagnelie PC, van Dusseldorp M, van Staveren WA,

Hautvast JG. Effects of macrobiotic diets on linear growth in infants and children until 10 years of age. Eur J Clin Nutr 1994;48 Suppl 1:S103–11; discussion S11-2.

55. Dagnelie PC, van Staveren WA. Macrobiotic nutrition and child health: results of a population-based, mixed-longitudinal cohort study in The Netherlands. Am J Clin Nutr 1994;59:1187S–96S.
56. Louwman MW, van Dusseldorp M, van de Vijver FJ, Thomas CM, Schneede J, Ueland PM, Refsum H, van Staveren WA. Signs of impaired cognitive function in adolescents with marginal cobalamin status. Am J Clin Nutr 2000;72:762–9.
57. Ruel M. Milk intake is associated with better growth in Latin America: evidence from the Demographic and Health Surveys. FASEB J 2003;17:A1199.
58. Allen LH. The nutrition CRSP: what is marginal malnutrition, and does it affect human function? Nutr Rev 1993;51:255–67.
59. Sigman M, McDonald MA, Neumann C, Bwibo N. Prediction of cognitive competence in Kenyan children from toddler nutrition, family characteristics and abilities. J Child Psychol Psychiatry 1991;32:307–20.
60. Wachs TD, Moussa W, Bishry Z, Yunis F, Sobhy A, McCabe G, Jerome N, Galal O, Harrison G, Kirksey A. Relations between nutrition and cognitive performance in Egyptian toddlers. Intelligence 1993;17:151–72.
61. Marquis GS, Habicht JP, Lanata CF, Black RE, Rasmussen KM. Breast milk or animal-product foods improve linear growth of Peruvian toddlers consuming marginal diets. Am J Clin Nutr 1997;66:1102–9.
62. Gittelsohn J, Shankar AV, West KP, Jr., Ram R, Dhungel C, Dahal B. Infant feeding practices reflect antecedent risk of xerophthalmia in Nepali children. Eur J Clin Nutr 1997;51:484–90.
63. Allen LH, Gillespie S. What works? A review of the efficacy and effectiveness of nutrition interventions. Nutrition policy paper 19. Geneva:United Nations Administrative Committee on Coordination Sub-Comittee on Nutrition, 2001.
64. Malcolm LA. Growth retardation in a New Guinea boarding school and its response to supplementary feeding. Br J Nutr 1970;24:297–305.
65. McLean ED, Allen LH, Neumann CG, Peerson JM, Siekmann JH, Murphy SP, Bwibo NO, Demment MW. Low plasma vitamin B-12 in Kenyan school children is highly prevalent and improved by supplemental animal source foods. J Nutr 2007;137:676–82.
66. Gibson RS, Yeudall F, Drost N, Mtitimuni BM, Cullinan TR. Experiences of a community-based dietary intervention to enhance micronutrient adequacy of diets low in animal source foods and high in phytate: a case study in rural Malawian children. J Nutr 2003;133:3992S–99S.
67. Creed-Kanashiro HM, Uribe TG, Bartolini RM, Fukumoto MN, Lopez TT, Zavaleta NM, Bentley ME. Improving dietary intake to prevent anemia in adolescent girls through community kitchens in a periurban population of Lima, Peru. J Nutr 2000;130:459S–61S.
68. Lartey A, Manu A, Brown KH, Peerson JM, Dewey KG. A randomized, community-based trial of the effects of improved, centrally processed complementary foods on growth and micronutrient status of Ghanaian infants from 6 to 12 mo of age. Am J Clin Nutr 1999;70:391–404.
69. Dalton A, Wolmarans P, Witthuhn RC, van Stuijvenberg ME, Swanevelder SA, Smuts CM. A randomised control trial in schoolchildren showed improvement in cognitive function after consuming a bread spread, containing fish flour from a marine source. Prostaglandins Leukot Essent Fatty Acids 2009;80:143–9.
70. Maulen-Radovan I, Villagomez S, Soler E, Villicana R, Hernandez-Ronquillo L, Rosado JL. [Nutritional impact of whole milk supplemented with vitamins and minerals in children]]. Salud Publica Mex 1999;41:389–96.
71. Rivera JA, Shamah T, Villalpando S, Monterrubio E. Effectiveness of a large-scale iron-fortified milk distribution program on anemia and iron deficiency in low-income young children in Mexico. Am J Clin Nutr 2010;91:431–9.
72. Villalpando S, Shamah T, Rivera JA, Lara Y, Monterrubio E. Fortifying milk with ferrous gluconate and zinc oxide in a public nutrition program reduced the prevalence of anemia in toddlers. J Nutr 2006;136:2633–7.
73. Sazawal S, Dhingra U, Dhingra P, Hiremath G, Kumar J, Sarkar A, Menon VP, Black RE. Effects of fortified milk on morbidity in young children in north India: community based, randomised, double masked placebo controlled trial. BMJ 2007;334:140–44.
74. Sazawal S, Dhingra U, Dhingra P, Hiremath G, Sarkar A, Dutta A, Menon VP, Black RE. Micronutrient fortified milk improves iron status, anemia and growth among children 1–4 years: a double masked, randomized, controlled trial. PLoS One 2010;5:e12167.
75. Lien do TK, Nhung BT, Khan NC, Hop le T, Nga NT, Hung NT, Kiers J, Shigeru Y, te Biesebeke R. Impact of milk consumption on performance and health of primary school children in rural Vietnam. Asia Pac J Clin Nutr 2009;18:326–34.
76. Hall A, Hanh TT, Farley K, Quynh TP, Valdivia F. An evaluation of the impact of a school nutrition programme in Vietnam. Public Health Nutr 2007;10:819–26.
77. Graham D, Kira G, Conaglen J, McLennan S, Rush E. Vitamin D status of Year 3 children and supplementation through schools with fortified milk. Public Health Nutr 2009;12:2329–34.
78. Virtanen MA, Svahn CJ, Viinikka LU, Raiha NC, Siimes MA, Axelsson IE. Iron-fortified and unfortified cow's milk: effects on iron intakes and iron status in young children. Acta Paediatr 2001;90:724–31.
79. Silva MR, Dias G, Ferreira CL, Franceschini SC, Costa NM. Growth of preschool children was improved when fed an iron-fortified fermented milk beverage supplemented with Lactobacillus acidophilus. Nutr Res 2008;28:226–32.
80. Szymlek-Gay EA, Ferguson EL, Heath AL, Gray AR, Gibson RS. Food-based strategies improve iron status in toddlers: a randomized controlled trial. Am J Clin Nutr 2009;90:1541–51.
81. Iost C, Name JJ, Jeppsen RB, Ashmead HD. Repleting hemoglobin in iron deficiency anemia in young children through liquid milk fortification with bioavailable iron amino acid chelate. J Am Coll Nutr 1998;17:187–94.
82. Rapetti MC, Donato H, de Galvagni A, Lubovitsky M, Lanzilotta M, Trepacka E, Burlando G, Weill R. Correction of iron deficiency with an iron-fortified fluid whole cow's milk in children: results of a pilot study. J Pediatr Hematol Oncol 1997;19:192–6.

83. Stekel A, Olivares M, Cayazzo M, Chadud P, Llaguno S, Pizarro F. Prevention of iron deficiency by milk fortification. II. A field trial with a full-fat acidified milk. Am J Clin Nutr 1988;47:265–9.
84. Neumann CG, Bwibo NO, Murphy SP, Sigman M, Whaley S, Allen LH, Guthrie D, Weiss RE, Demment MW. Animal source foods improve dietary quality, micronutrient status, growth and cognitive function in Kenyan school children: background, study design and baseline findings. J Nutr 2003;133:3941S–49S.
85. Grillenberger M, Neumann CG, Murphy SP, Bwibo NO, van't Veer P, Hautvast JG, West CE. Food supplements have a positive impact on weight gain and the addition of animal source foods increases lean body mass of Kenyan schoolchildren. J Nutr 2003;133:3957S–64S.
86. Cuevas-Nasu L, Hernandez-Prado B, Shamah-Levy T, Monterrubio EA, Morales-Ruan Mdel C, Moreno-Macias LB. Overweight and obesity in school children aged 5 to 11 years participating in food assistance programs in Mexico. Salud Publica Mex 2009;51 Suppl 4:S630–7.
87. Torres MA, Lobo NF, Sato K, Queiroz Sde S. [Fortification of fluid milk for the prevention and treatment of iron deficiency anemia in children under 4 years of age]. Rev Saude Publica 1996;30:350–7.
88. Olivares M, Walter T, Hertrampf E, Pizarro F, Stekel A. Prevention of iron deficiency by milk fortification. The Chilean experience. Acta Paediatr Scand Suppl 1989; 361:109–13.
89. Sabikhi L. Designer milk. Adv Food Nutr Res 2007; 53:161–98.
90. Svahn JC, Feldl F, Raiha NC, Koletzko B, Axelsson IE. Fatty acid content of plasma lipid fractions, blood lipids, and apolipoproteins in children fed milk products containing different quantity and quality of fat. J Pediatr Gastroenterol Nutr 2000;31:152–61.
91. Dewey KG. Guiding principles for complementary feeding of the breastfed child. Geneva: Pan American Health Organization and World Health Organization, 2004.
92. Wijndaele K, Lakshman R, Landsbaugh JR, Ong KK, Ogilvie D. Determinants of early weaning and use of unmodified cow's milk in infants: a systematic review. J Am Diet Assoc 2009;109:2017–28.
93. Hernell O. Human milk vs. cow's milk and the evolution of infant formulas. Nestle Nutr Workshop Ser Pediatr Program 2011;67:17–28.
94. Allen LH. Maternal micronutrient malnutrition: effects on breast milk and infant nutrition, and priorities for intervention. SCN News 1994;11:21–4.
95. Brunken GS, Silva SM, Franca GV, Escuder MM, Venancio SI. Risk factors for early interruption of exclusive breastfeeding and late introduction of complementary foods among infants in midwestern Brazil. J Pediatr (Rio J) 2006;82:445–51.
96. Bhandari N, Kabir AK, Salam MA. Mainstreaming nutrition into maternal and child health programmes: scaling up of exclusive breastfeeding. Matern Child Nutr 2008;4 Suppl 1:5–23.
97. German JB, Freeman SL, Lebrilla CB, Mills DA. Human milk oligosaccharides: evolution, structures and bioselectivity as substrates for intestinal bacteria. Nestle Nutr Workshop Ser Pediatr Program 2008;62:205–18; discussion 18–22.
98. Sela DA, Chapman J, Adeuya A, Kim JH, Chen F, Whitehead TR, Lapidus A, Rokhsar DS, Lebrilla CB, German JB, Price NP, Richardson PM, Mills DA. The genome sequence of Bifidobacterium longum subsp. infantis reveals adaptations for milk utilization within the infant microbiome. Proc Natl Acad Sci U S A 2008; 105:18964–9.
99. Ziegler EE. Adverse effects of cow's milk in infants. Nestle Nutr Workshop Ser Pediatr Program 2007;60:185–96; discussion 96–9.
100. Fernandes SM, de Morais MB, Amancio OM. Intestinal blood loss as an aggravating factor of iron deficiency in infants aged 9 to 12 months fed whole cow's milk. J Clin Gastroenterol 2008;42:152–6.
101. Jiang T, Jeter JM, Nelson SE, Ziegler EE. Intestinal blood loss during cow milk feeding in older infants: quantitative measurements. Arch Pediatr Adolesc Med 2000;154:673–8.
102. Wilson JF, Lahey ME, Heiner DC. Studies on iron metabolism. V. Further observations on cow's milk-induced gastrointestinal bleeding in infants with iron-deficiency anemia. J Pediatr 1974;84:335–44.
103. Ziegler EE, Fomon SJ, Nelson SE, Rebouche CJ, Edwards BB, Rogers RR, Lehman LJ. Cow milk feeding in infancy: further observations on blood loss from the gastrointestinal tract. J Pediatr 1990;116:11–8.
104. Sullivan PB. Cows' milk induced intestinal bleeding in infancy. Arch Dis Child 1993;68:240–5.
105. Koletzko B, von Kries R, Monasterolo RC, Subias JE, Scaglioni S, Giovannini M, Beyer J, Demmelmair H, Anton B, Gruszfeld D, Dobrzanska A, Sengier A, Langhendries JP, Cachera MF, Grote V. Infant feeding and later obesity risk. Adv Exp Med Biol 2009;646:15–29.
106. Koletzko B, von Kries R, Closa R, Escribano J, Scaglioni S, Giovannini M, Beyer J, Demmelmair H, Gruszfeld D, Dobrzanska A, Sengier A, Langhendries JP, Rolland Cachera MF, Grote V. Lower protein in infant formula is associated with lower weight up to age 2 y: a randomized clinical trial. Am J Clin Nutr 2009;89:1836–45.
107. Dorosty AR, Emmett PM, Cowin S, Reilly JJ. Factors associated with early adiposity rebound. ALSPAC Study Team. Pediatrics 2000;105:1115–8.
108. Benhamou AH, Schappi Tempia MG, Belli DC, Eigenmann PA. An overview of cow's milk allergy in children. Swiss Med Wkly 2009;139:300–7.
109. Poddar U, Yachha SK, Krishnani N, Srivastava A. Cow's milk protein allergy: an entity for recognition in developing countries. J Gastroenterol Hepatol 2010;25:178–82.
110. Carvalho NF, Kenney RD, Carrington PH, Hall DE. Severe nutritional deficiencies in toddlers resulting from health food milk alternatives. Pediatrics 2001;107:E46.
111. Infant and young child nutrition. Geneva: Fifty-fourth World Health Assembly, 2001. Available at: http://www.who.int/nutrition/topics/WHA54.2_iycn_en.pdf
112. Heyman MB. Lactose intolerance in infants, children, and adolescents. Pediatrics 2006;118:1279–86.
113. Wang Y, Li S. Worldwide trends in dairy production and consumption and calcium intake: is promoting consumption of dairy products a sustainable solution for inadequate calcium intake? Food Nutr Bull 2008;29:172–85.
114. Sampson HA. Update on food allergy. J Allergy Clin Immunol 2004;113:805–19; quiz 20.

115. Motarjemi Y, Kaferstein F, Moy G, Quevedo F. Contaminated weaning food: a major risk factor for diarrhoea and associated malnutrition. Bull World Health Organ 1993;71:79–92.
116. Reference manual for U.S. milk powders. Arlington, Virginia: United States Dairy Export Council, 2005.
117. Hoppe C, Andersen GS, Jacobsen S, Molgaard C, Friis H, Sangild PT, Michaelsen KF. The use of whey or skimmed milk powder in fortified blended foods for vulnerable groups. J Nutr 2008;138:145S–61S.
118. Allen LH dBB, Dary O, Hurrell R. Guidelines for food fortification with micronutrients. Geneva: World Health Organization, 2006.
119. Mills EW, Seetharaman K, Maretzki AN. A nutribusiness strategy for processing and marketing animal-source foods for children. J Nutr 2007;137:1115–8.
120. Global Health Risks: mortality and burden of disease attributable to selected major risks. Geneva: World Health Organization, 2009.
121. Horton S. RJ. The economics of iron deficiency. Food Policy 2003;28:51–75.
122. Horton S. The economics of food fortification. J Nutr 2006;136:1068–71.
123. Black RE, Allen LH, Bhutta ZA, Caulfield LE, de Onis M, Ezzati M, Mathers C, Rivera J. Maternal and child undernutrition: global and regional exposures and health consequences. Lancet 2008;371:243–60.
124. Repositioning nutrition as central to development. World Bank, 2006.
125. Alderman H, Hoddinott J, Kinsey B. Long term consequences of early childhood malnutrition. World Bank, 2003.
126. Stein AD, Wang M, Martorell R, Norris SA, Adair LS, Bas I, Sachdev HS, Bhargava SK, Fall CH, Gigante DP, Victora CG. Growth patterns in early childhood and final attained stature: data from five birth cohorts from low- and middle-income countries. Am J Hum Biol 2010; 22:353–9.
127. Bruinsma J. World agriculture: towards 2015/2030. An FAO perspective. Rome: Food and Agriculture Organization of the United Nations, 2003.
128. FAOSTAT. Available at: http://faostat.fao.org Accessed 6/22/2010.
129. Knips V. Developing countries and the global dairy sector. Rome: Food and Agriculture Organization, 2005.