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Dairy's Impact on Reducing Global Hunger

Global Agenda for Sustainable Livestock

Dairy's Impact on Reducing

Global Hunger

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PREFACE

More than 800 million people are suffering from hunger on our planet. This hunger includes chronic food deprivation and malnutrition in the form of nutrient and micronutrient deficiencies as well as shortfalls in vitamins and essential metals. The majority of these people live in low- and middle-income countries and mostly in rural areas. They largely depend on agriculture and livestock.

This study provides quantitative evidence for the potential impact dairying can have in eradicating hunger (SDG 2) and showing the role dairy products play in providing balanced, healthy and safe nutrition.

Eradication of hunger is among the greatest global challenges today and an indispensable requirement for sustainable development. Driven by population and economic growth, particularly in developing countries, the need for livestock products will increase substantially in the coming 30 years. The livestock sector in general, and the dairy sector in particular, will help address this challenge by promoting food security and nutrition, sustained economic growth and inclusive social development, all while using natural resources efficiently.

The Global Agenda for Sustainable Livestock (GASL), established in 2011, is a multi-stakeholder partnership mechanism which aims to catalyze and guide the sustainable development of the global livestock sector. It provides a platform to comprehensively address the sectors' multiple sustainable development challenges by facilitating the global dialogue into local practice change, focusing on innovation, capacity building, incentive systems and enabling environments.

The achievements of GASL have proven that multi-stakeholder partnerships are a powerful collaborative approach to support the implementation of SDGs on issues related to livestock. Our vision is to enhance the livestock sector's contribution to sustainable development. The mission is to strengthen livestock stakeholders' commitment, investments and adoption of good practices and policies in support of the UN Agenda 2030. The sector's sustainability can only be improved effectively through concerted action by all stakeholder groups. Given the public good nature of the sector's environmental, social and economic challenges and its increasing economic integration, collective global action is essential.

Therefore, the strategic approach in the Global Agenda has evolved from a first phase where the seven stakeholder Clusters (public sector, social movements, private sector, donors, academia, NGOs, and inter-governmental and multi-lateral organizations) were the main focus in order to consolidate the multi-stakeholder vision, to a new phase where the Action Networks have been prioritized to foster knowledge production, pilots and practical impact at local level. The Action Networks are the specific technical initiatives GASL liaises with to foster concrete livestock sustainability aspects.

In this framework, the Livestock for Social Development Action Network, established in 2017, has initiated the production of a series of prospective papers on the impact of dairy on the most relevant social SDGs through the joint effort of the Global Dairy Platform (GDP) and the IFCN-Dairy Network. The first publication, "Dairy Development's Impact on Poverty Reduction," (SDG 1) was published in 2018. This paper on the role of dairy products in eradicating hunger is the second (SDG 2).

I congratulate M.J. Otte and A. Felis Rota for their work on this report, along with E. Reyes. I also thank Shirley Tarawali and her team at the International Livestock Research Institute (ILRI) for their valuable input.

Fritz Schneider

Chair
Global Agenda for Sustainable Livestock

SUMMARY

| Background |

In 2015, the 193 Member States of the United Nations adopted the 17 Sustainable Development Goals (SDGs), which aim to end poverty (SDG1) and hunger (SDG2), among other things, while restoring and sustainably managing natural resources. In 2017, 821 million people globally were estimated to be suffering from hunger, i.e. chronic food deprivation resulting in undernourishment. Chronic undernourishment is particularly damaging when it affects children and results in stunting. Stunting is largely irreversible and associated with reduced intellectual development, reduced productivity, and increased risk of chronic disease in later life. Given stunting's far-reaching consequences for human development, SDG2 specifically calls for a 40% reduction in the number of children under 5 yrs of age who are stunted by 2025. Providing animal-sourced food (ASF) to malnourished children has demonstrable nutritional benefits, and ASF including milk or dairy product intake has been widely associated with child growth. In light of the recognized potential of dairy development to contribute to poverty reduction (SDG1), and the strong biological arguments for a positive effect of milk consumption on child growth and health, this study assessed the evidence for a causal relationship between (i) milk/dairy consumption and (ii) ownership of dairy animals, and child growth in low- and middle-income countries (LMICs).

| Approach |

A systematic literature search was conducted using Google Scholar, IngentaConnect, JSTOR, Repec, and Web of Science databases to identify studies providing valid quantitative information on the potential impacts of dairy animal ownership and milk/dairy consumption on child growth (0 to 19 years). Reference lists of review papers and papers meeting inclusion criteria were scanned to identify additional studies possibly meeting inclusion criteria. To maximize the validity of causal inference, only randomized controlled trials and observational studies with a comparison group that were controlled for confounding were included in the review.

A total of 20 studies from sub-Saharan Africa and Asia were eligible for inclusion in the review based on the aforementioned criteria. Of these, 13 investigated the relationship between dairy consumption and child growth, while 7 studies assessed the association between cow/goat ownership and production and child growth. Intervention trials predominate in the first group (8/13), while observational studies (with a control group) form the majority of studies in the second group (5/7).

| Findings |

A positive association between milk consumption and child height/length was found in 16 of 17 comparisons, with one study not reporting the direction of impact. Statistically, the difference was significant at the 5% level in 10 out of 18 comparisons. Likewise, all comparisons related to child body weight found a positive association with milk consumption, with 7 of 12 differences being statistically significant at the 5% level. In the randomized controlled dairy protein supplementation trials, differences in daily and cumulative height and weight gain (n=7) were highly correlated with the amounts of supplementary dairy protein provided to the intervention groups (r=0.89 to 0.96, p<0.01).

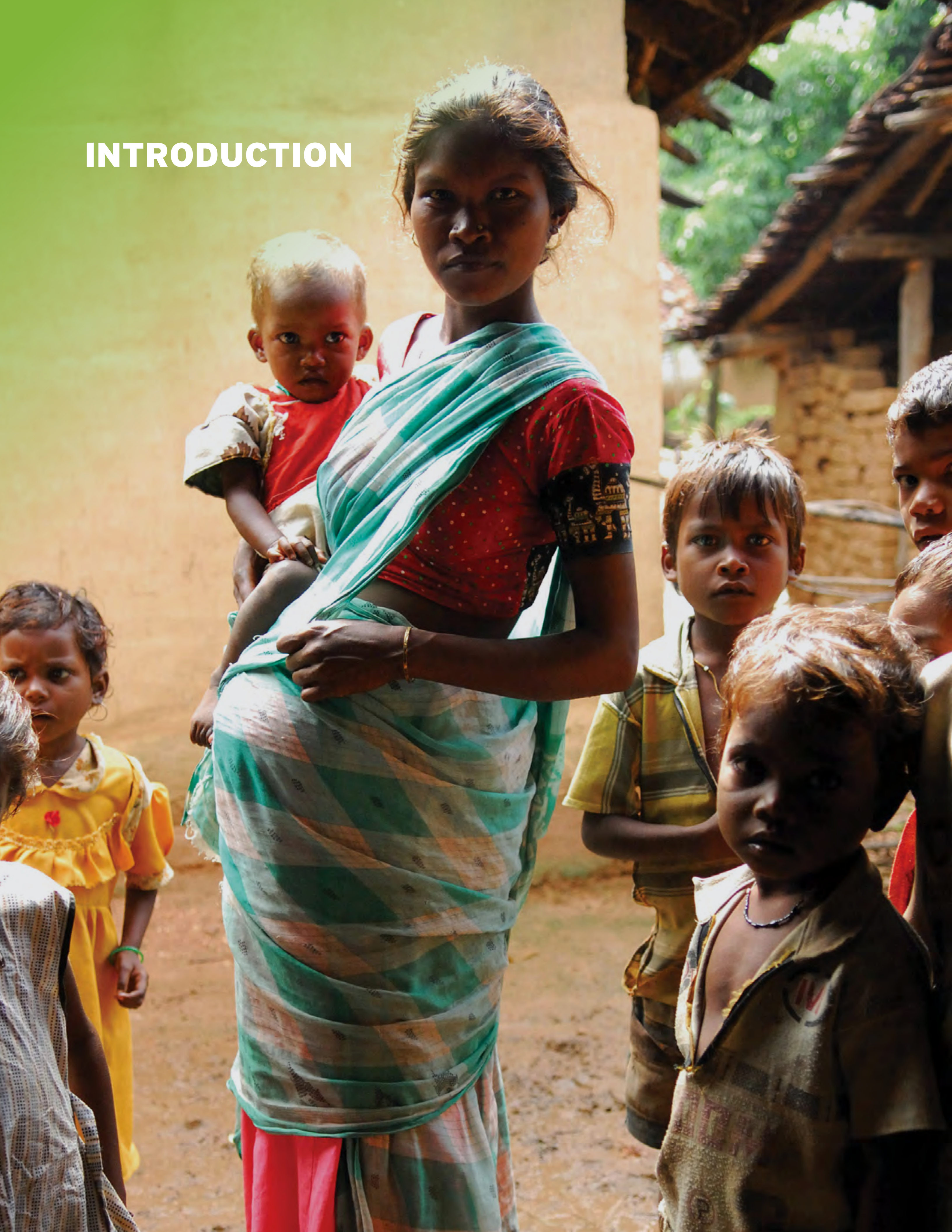
With respect to the effect of dairy animal ownership, milk consumption was consistently and mostly significantly higher in households owning cattle/goats than in the comparison group. All 14 comparisons of child height/length found a positive association with the estimated effect being significant at the 10% level in a two-sided test in 10 of the 14 comparisons. Similarly, 4 out of 5 comparisons related to child weight found a positive association but the difference was statistically significant in one case only (0 to 5-year age group).

The remarkable consistency of the positive association between dairy animal ownership, milk/dairy intake, and child growth across the experimental and observational studies, and the dose-response relationship between dairy consumption and child growth seen across the randomized controlled supplementation trials provide strong evidence that, in rural low-income settings, household milk production increases household milk consumption, and increased milk consumption results in improved child growth and reduced stunting.

| Recommendations |

Further multidisciplinary research is required to identify key elements of dairy development that maximize its impact towards achieving SDG2. For instance, dairy development needs to be accompanied by nutrition education of caregivers to ensure that milk is provided in the most critical phase of childhood, namely in the 0.5 to 2-year age group. Furthermore, given milk is a potential medium for a variety of pathogens to which children may be particularly vulnerable, appropriate awareness creation and training at the household level, and food safety systems need to be put in place to support public health when expanding the dairy sector.

INTRODUCTION



In 2015, the 193 Member States of the United Nations adopted the Sustainable Development Goals (SDGs)[1] to guide development actions of governments, international agencies, civil society and other institutions over 15 years (2016–2030). Among other things, the SDGs aim to end poverty (SDG1) and hunger (SDG2)[2] while restoring and sustainably managing natural resources. The SDGs integrate the three dimensions of sustainable development – economic, social and environmental – and mutually depend on each other.

In the SDG context, 'hunger' is defined as chronic food deprivation resulting in undernourishment. Given the lack of nationally representative dietary intake surveys worldwide, the number of people suffering from hunger is estimated using information on dietary energy supply from Food Balance Sheet data.

In 2017, **the number of people in the world suffering from hunger was estimated to be around 821 million** (approximately one out of every nine people worldwide).

This figure represents an increase in the number of 'hungry' people by 40 million since 2014 and points to a reversal of the declining trend in undernourishment seen since 2005 (FAO 2018). Chronic undernourishment is particularly damaging when it affects children and results in stunting, which is defined as height being at least two standard deviations less than the median height of a well-nourished child of the same age and sex.

Stunting is largely irreversible and associated with **reduced intellectual development**, **reduced productivity**, and **increased risk of chronic disease in later life** (Victora *et al.* 2008)

Globally, approximately 151 million children under 5 years of age are considered stunted, i.e. chronically undernourished (UNICEF 2018). Given stunting's far-reaching consequences for human development, SDG2 specifically calls for action to reach the global nutrition target of a 40% reduction in the number of children under 5 who are stunted by 2025 (WHO 2014).

Child growth failure occurs mainly in the first two years of life (Victora *et al.* 2010) starting at around 6 months of age, a time when breast milk can no longer provide all nutrients required for healthy growth and development, which requires the introduction of

[1] A set of 17 aspirational objectives (SDGs) with 169 targets.
[2] In full: "End hunger, achieve food security and improved nutrition and promote sustainable agriculture."

complementary foods {WHO 2009}. The provision of mainly plant-based complementary foods that are low in high-quality protein and micronutrients, such as rice, wheat, maize or starchy roots and tubers, are considered an important factor in child undernutrition (Leroy and Frongillo 2007).

Given their relatively small digestive system vis-à-vis nutrient requirements, **in the absence of fortified foods, it is difficult for young children to meet their micronutrient needs without daily intake of animal-sourced foods** (ASFs) (PAHO/WHO 2003).

Providing ASFs to malnourished children in the first 1,000 days of life has demonstrable nutritional benefits (Grace *et al.* 2018) and experts agree that ASF, such as dairy products, are the "first and most effective choice to treat moderately malnourished children" (Lagrange 2009). Dairy is high in macronutrients (carbohydrates, fat and protein), as well as important micronutrients such as vitamin A, vitamin B_{12}, and calcium (Murphy and Allen 2003), and milk or dairy product intake has been associated with child growth in both wealthier and poorer populations (Allen 2012).

In light of the international commitment to reduce hunger, the paramount importance of adequate nutrition in early childhood, the growing body of literature on the role of ASFs as complementary food to ensure adequate micronutrient intake and the recognized potential of dairy development to contribute to poverty reduction (SDG1) (FAO, GDP and IFCN 2018), the aim of this study is to collate and review available evidence for a positive and causal relationship between:

(i) milk/dairy consumption, and
(ii) ownership of dairy animals

and child growth in Low- and Middle-Income Countries (LMICs as defined by the World Bank, 2019).

PREVIOUS REVIEWS AND EVIDENCE OF CAUSALITY

PREVIOUS REVIEWS AND EVIDENCE OF CAUSALITY

Despite strong biological arguments for a positive effect of milk consumption on child growth and the fairly consistent association between milk consumption/dairy cow ownership and child growth, the majority of previously conducted reviews in the literature conclude that the strength of evidence for a causal relationship is moderate (e.g. Allen and Dror 2011, de Beer 2012, Iannotti *et al.* 2013, Leroy and Frongillo 2007, Masset *et al.* 2011, details in Annex 1). In a number of intervention studies, vitamins and micronutrients were provided in addition to milk supplementation and some lacked randomization, while observational studies often suffered from insufficient control for confounding[3]. Although studies generally reported a positive impact on diets, improved diets did not necessarily coincide with improvements in biochemical/clinical indicators and/or child anthropometry.

Figure 1 provides a schematic overview of the assumed causal pathway between dairy animal ownership/dairy consumption and nutrition outcomes and commonly applied metrics for the latter.

As the figure shows, household endowments ('wealth') are likely to strongly influence all elements along the surmised pathway, i.e. **'wealthier' households are likely to consume more diverse and larger quantities of food, and, given better standards of sanitation**, less likely to suffer from disease interfering with food utilization.

In predominantly agrarian economies, wealthier households are also more likely to own dairy animals, mainly cattle, than their poorer counterparts and thus dairy animal ownership itself is likely to be confounded with 'wealth'. In addition to this internal validity concern, another caveat mentioned is that much of the observational evidence is confined to East Africa, so external validity may also be compromised (Choudhury *et al.* 2018).

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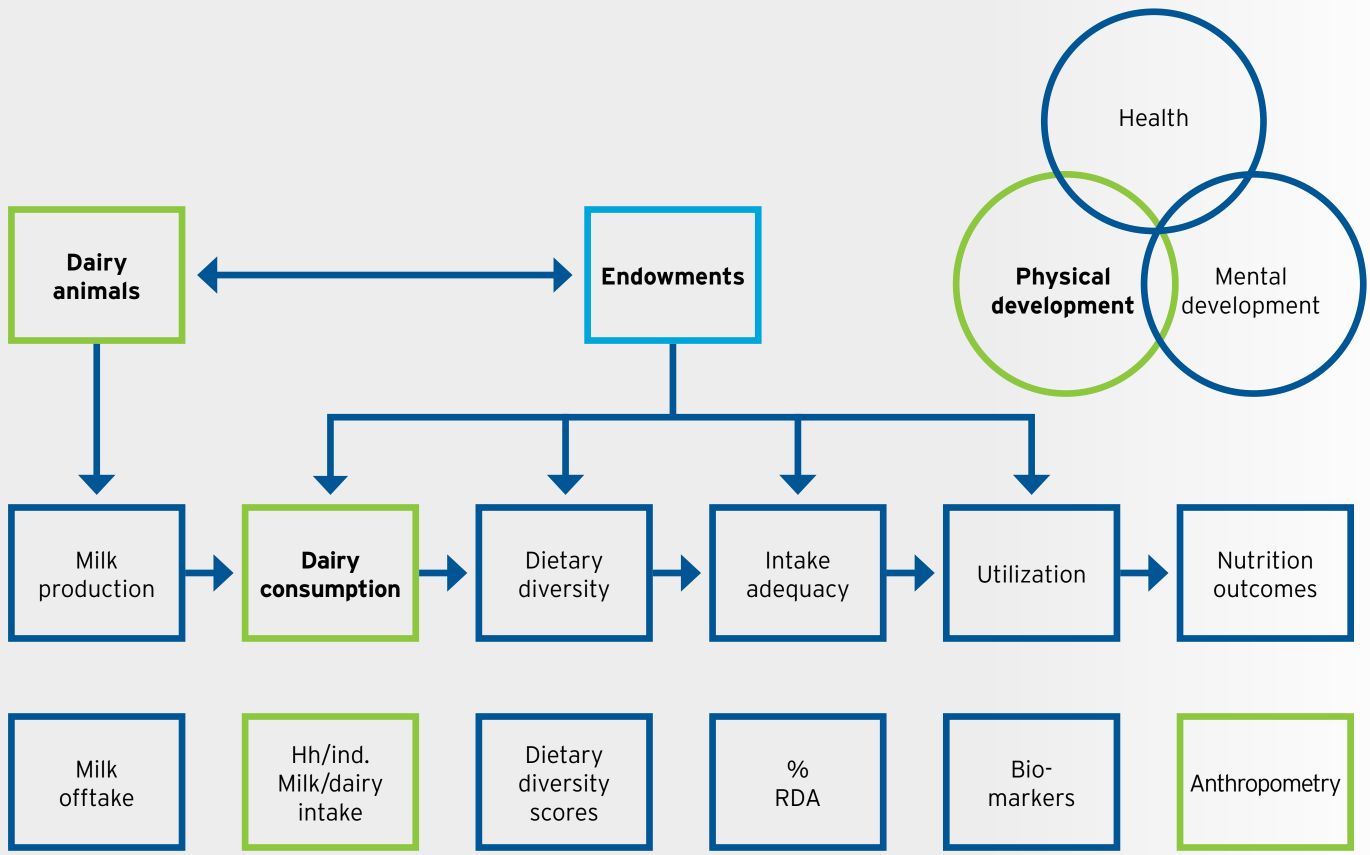
[3] Confounding occurs when the effect or association between the 'treatment' (or exposure) and outcome is distorted by the presence of another variable.

Figure 1: Impact pathways of dairy animal ownership/dairy consumption on child growth and respective indicators



Randomized controlled trials (RCTs) are considered the gold standard for causal inference. However, RCTs are best suited for situations in which the causal link between intervention and effect is relatively strong and simple. Victora *et al.* (2004) argue that RCTs are often inappropriate for the scientific assessment of large-scale public health interventions. They suggest that studies with 'plausibility' designs, i.e. observational studies with a comparison group, may often be the only feasible option for assessing large-scale interventions and that they can provide valid evidence of causal impact. For example, findings demonstrating changes in the various links along the surmised causal pathway can provide strong plausibility support that change is attributable to the intervention. Consistency between studies and a dose-response relationship are further elements strengthening the case for a causal relationship between intervention and measured effect in observational studies (Hill 1965).

METHODS

Defining relevant studies

Intervention trials and observational studies were eligible for inclusion in this review if they were original works (excluding reviews) published in a peer-reviewed journal or as full papers in conference proceedings (conference abstracts were not included) from the year 2000 onwards and:

- were carried out in Low- and Middle-Income Countries,
- involved children in the age range 0–19 years,
- reported anthropometric measurements (height, weight, HAZ[4], or WAZ[5]),
- quantified dairy consumption (either as likelihood of consumption or amount consumed at least at household level), and
- controlled for confounding by statistical techniques and/or by using a control group.

Intervention trials with milk or milk products were excluded if they lasted for less than 6 months or if the trial did not involve a control group without dairy protein supplementation. Studies evaluating fortified milk programs, i.e. milk used as vehicle to deliver micronutrients, as well as studies on the effect of milk proteins in blended ready-to-use therapeutic or supplementary foods (RUSTF/RUSF) for the treatment of severe acute malnutrition were also excluded.

Search strategy

Google Scholar, IngentaConnect, JSTOR, Repec, and Web of Science were searched using the search strings: 'Milk', 'dairy', or 'dairy animals' paired with 'food (in)security', 'malnutrition', 'undernourishment', 'stunting', 'underweight', 'wasting', 'body mass index', (BMI), 'dietary energy supply', (DES). Additional papers were identified through searches of reference lists of systematic reviews and key studies identified in the review process.

Screening process

The first step in the screening process involved the removal of duplicate titles found in the searched databases. Thereafter titles were screened, and papers unequivocally not related to the topic of interest or falling under exclusion criteria were removed. Subsequently, abstracts of the remaining papers were reviewed and papers clearly not fulfilling the inclusion criteria were eliminated. Full copies of all papers deemed potentially eligible were retrieved for closer examination to determine whether or not they met all eligibility criteria. Reference lists from assessed articles and relevant reviews (Allen and Dror 2011, de Beer 2012, Iannotti *et al.* 2013, Hoppe *et al.* 2006, Leroy and Frongillo 2007, Masset *et al.* 2011) were scanned for eligible studies and those potentially fulfilling inclusion criteria were retrieved and subjected to the same examination as the papers selected for inclusion in the review.

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[4] Height-for-age Z-score, 'stunting' defined as ≥ 2 standard deviations below the WHO Child Growth Standards median

[5] Weight-for-age Z-score, 'underweight' defined as ≥2 standard deviations below the WHO Child Growth Standards median

Data extraction and synthesis

The following information was extracted and tabulated for all studies included in the review: country, study design, source of data, number and age group of participants, dairy consumption, and anthropometric data. For dairy supplementation studies, the method of randomization, the type and amount of dairy supplement, frequency of provision, duration of intervention, sex of participants, baseline height and weight, and height and weight change were added to the list. Where not stated in the paper, the amount of dairy protein provided per meal was calculated assuming a protein content of 32g/L milk (Gebhardt and Robin 2002). The cumulative amount of additional dairy protein consumed over the duration of the trial was estimated by multiplying information provided in the papers on the average number of supplements consumed by the intervention group with the amount received per supplement. Where papers did not provide information on the average number of supplements consumed, the cumulative amount of additional protein was estimated using the information on length of the trial and frequency and amount of supplementation. For observational studies, the approach taken to control for confounding was included in the list of essential information items.

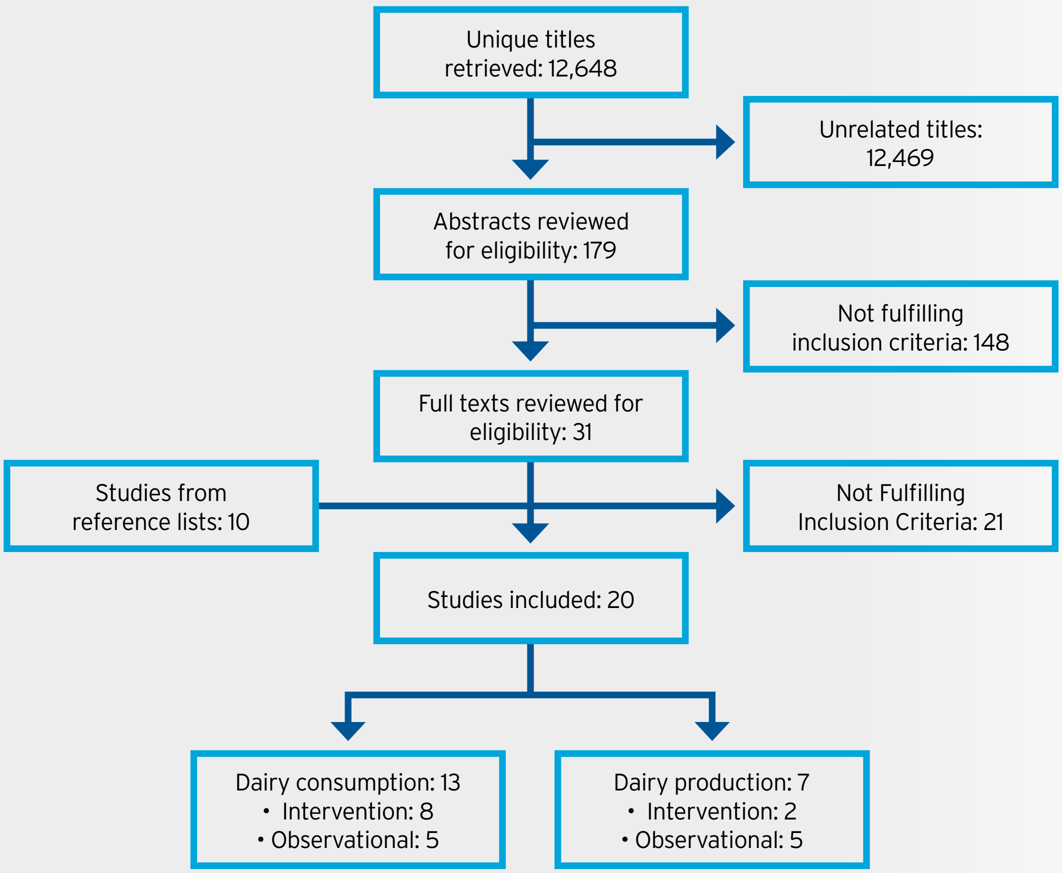
RESULTS

RESULTS

Search and selection process

The database search resulted in a combined list of 18,399 references of which 5,751 were duplicates resulting in 12,641 unique titles. The subsequent selection process is schematically represented in Figure 2.

Figure 2: **Schematic representation of the selection of literature for the review**



Based on rigorous application of in/exclusion criteria a total of 20 papers were included in this review. Of these 20 papers, 13 investigated the relationship between dairy consumption and child growth while 7 papers assessed the possible link between dairy production and child growth. Intervention trials predominate in the first group (8/13) while observational studies (with a control group) form the majority of studies in the second group (5/7).

Milk / dairy consumption and child growth

Intervention trials: The literature search yielded eight eligible intervention studies investigating the effect of dairy protein on child height and weight gain, three of which involved additional provision of vitamins and minerals (Table 1). The amount of dairy protein provided to the intervention group ranged from 6 to 16g per day of supplementation while the length of the trial period ranged from 6 to 24 months, leading to vastly different amounts of cumulative dairy protein supplementation between studies (range: 1 to 6kg of dairy protein). Further heterogeneity between studies existed in age groups (pre-school vs. school-age children, narrow vs. wide age range), randomization procedure (individual, class, school), and nutritional status of the study population (details in Annex 3).

Table 1: Summary of data from intervention studies on the effect of milk / dairy supplementation and child growth

Study	Age group (y)	Dairy protein / day (g)	Duration (m)	Total protein provided (g)	Difference in change of	
					Height (cm)	Weight (kg)
Supplementation with dairy protein only						
Du *et al.* 2004 and 2005 China	10	10.6	24	5,879	1.2**	1.50**
Grillenberger *et al.* 2003 Kenya	6 to 14	6.1	18	2,392	0.34ns[1]	0.37*[1]
He *et al.* 2005[2] China	3 to 5	3.8	9	745	0.2*	0.22*
Ihab *et al.* 2014[2] Indonesia	2 to 10	16.0	6	2,928	1.0*	0.80ns
Lien *et al.* 2009 Vietnam	7 to 8	16.0	6	2,510	0.4ns	0.40ns
Supplementation with dairy protein, vitamins and minerals						
Bhandari *et al.* 2001[3] India	0.3 to 1	8.0	8	1,952	0.4ns	0.25*
Hall *et al.* 2007[4] Vietnam	6 to 9	6.4	17	1,107	0.27**	0.24**
Lee *et al.* 2018[5] Ghana	6 to 9	8.8	9	1,012	0.0ns	0.04ns

^ p<0.1; * p<0.05; ** p<0.01; ns: p>0.1

[1] Difference against equicaloric non-milk supplemented controls 0.00 (ns) and -0.03 (ns) respectively. Among stunted children at baseline, milk group children gained 1.3 cm more height (15%) than controls (p=0.05).

[2] Children with below average HAZ and/or WAZ

[3] Plus cereal with vitamins and minerals

[4] Plus biscuits with vitamins and minerals

[5] Skimmed milk powder + micronutrients vs. micronutrients only in control group; change in HAZ / WAZ score

RESULTS

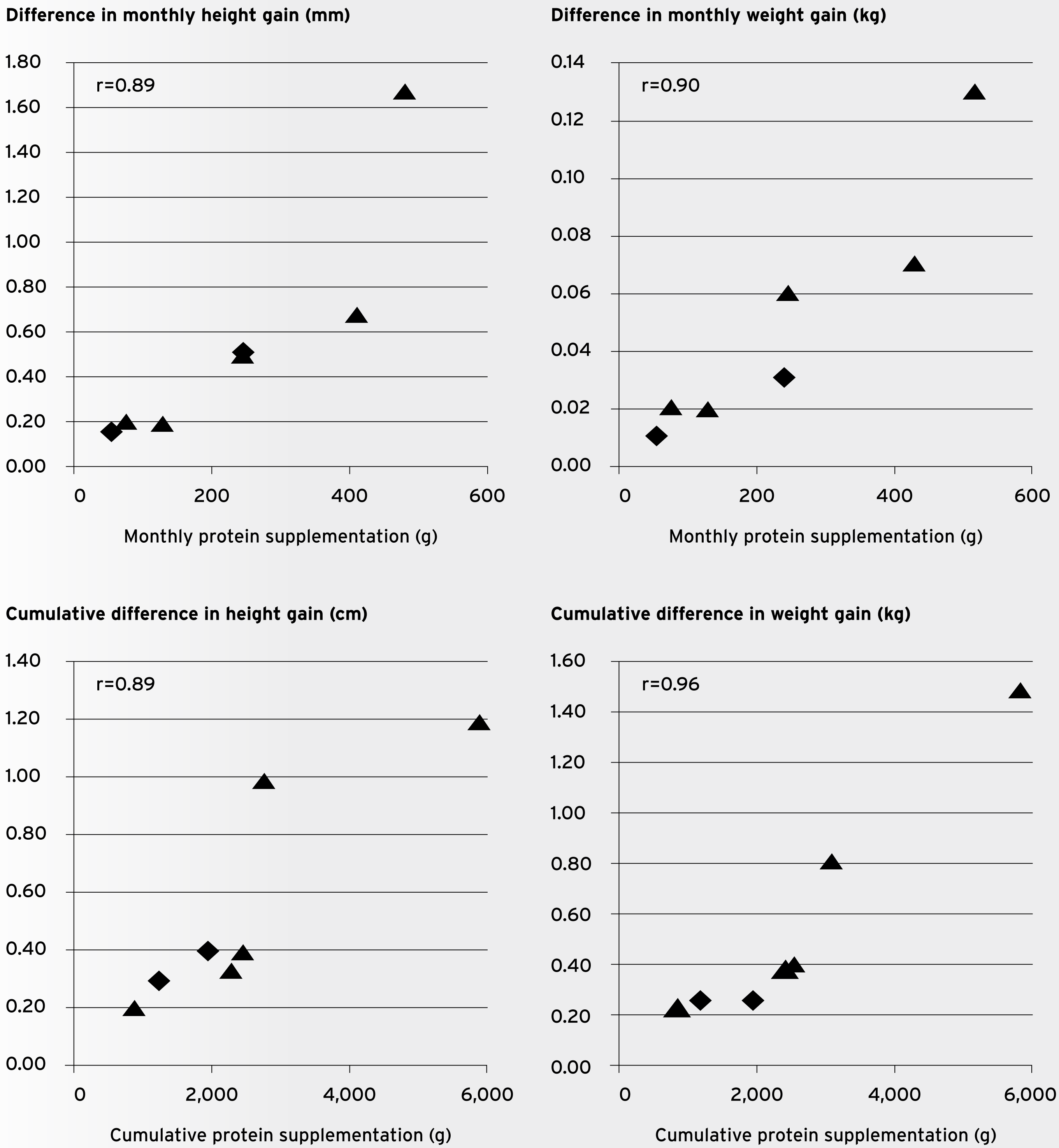
In seven of the eight studies, the change in height was greater in the supplemented group vs a non-milk control, with the difference being statistically significant ($p<0.05$) or highly significant ($p<0.01$) in four of the studies. One study (Lee *et al.* 2018) reported no difference in the change of HAZ score between supplemented and control groups. Weight gain was higher in the supplemented group in all eight studies, with the difference being statistically significant ($p<0.05$) in five of the eight studies. Bhandari *et al.* (2001) observed a reduction in breastfeeding in the supplemented children that may have been large enough to limit the impact of the intervention.

With regards to assessed biomarkers, Du *et al.* (2004) found that children who received the milk supplement had lower plasma concentrations of calcium as well as a significant increase in bone mineralization, and suggested that consumption of the milk supplement may have directed more calcium into growing bone, potentially leading to the observed increase in height. Lien *et al.* (2009) found that milk consumption increased mean serum zinc concentrations beyond the increase observed in the control group, indicating that a relatively moderate increase in zinc intake could improve zinc status and related health benefits.

Across studies, the **differences in monthly height and weight gain between supplemented groups and controls correlated highly with the amount of supplemental dairy protein** ($r=0.89$ and $r=0.90$ for height and weight respectively, $p<0.01$.).

The cumulative differences in height and weight gain over the duration of the trials was highly correlated with the estimated amounts of total additional milk protein received by the intervention group ($r=0.89$ and $r=0.96$ for height and weight respectively, $p<0.01$) (Fig. 3).

Figure 3: **Relationship between milk protein supplementation and difference in height and weight gain between intervention and control group (diamonds represent 2 trials with additional provision of vitamins and minerals)**



RESULTS

Observational studies: Five studies relating milk/dairy consumption and child growth met the selection criteria (Table 2 and Annex 3). Two studies, Fratkin *et al.* (2004) and Iannotti and Lesorogol (2014a), both carried out in Kenya, were longitudinal in nature and involved repeat surveys of the same households measuring milk consumption and physical development of children. While Fratkin *et al.* (2004) found that the amount of milk consumed was always a statistically significant determinant of child weight and height change, regardless of drought or non-drought times and breastfeeding status, Iannotti and Lesorogol (2014a) did not find a statistically significant relationship between child milk consumption and growth. Although the study of Iannotti and Lesorogol (2014a) was longitudinal, child anthropometry was only assessed once on a subset of the original sample resulting in a much smaller number of observations, and thus lower statistical power, compared to Fratkin *et al.* (2004). In a parallel publication Iannotti and Lesorogol (2014b) state that milk was a predominant source of critical micronutrients such as vitamins A, B12, and C and that reduced household milk consumption was linked to household nutrient inadequacy and child undernutrition.

Table 2: Summary of the results of observational studies on the effect of milk/dairy consumption (measures reported in notes under the table) and child growth

Study	Stratum	Dairy consumption	Age group	Estimated effect		
				Stunting	HAZ	WAZ
Fratkin *et al.* 2004 Kenya		0.1 to 3.6[1]	0 to 9y	-0.15**	--	--
Headey *et al.* 2018 46 countries	LAC	57.7[2]	1.5 to <2y	-0.044**	--	--
	NENA	64.9		-0.002ns	--	--
	SC&E Asia	38.4		-0.048**	--	--
	W&C Africa	20.8		-0.007ns	--	--
	E&S Africa	18.7		-0.066**	--	--
Hoorweg *et al.* 2000 Kenya	Dairy HHs & consumers	222 (≈220)[3]	0.5 to <5y	--	+*[5]	+**[5]
	Rural population	11 (51)				
Iannotti & Lesorogol 2014a Kenya		285[3,4]	0 to 5y	--	ns[6]	ns[6]
Kidoido & Korir 2015 Tanzania	Low income HHS	33 (86)[3]	0 to 6y	--	0.13**	0.40**
	High income HHS	41 (89)[3]	0 to 6y	--	0.09ns	0.06ns

^ p<0.1; * p<0.05; ** p<0.01; ns: p>0.1

Abbreviations: LAC = Latin American and the Caribbean, NENA = Near East and North Africa, SC&E Asia = South, Central and East Asia, W&C Africa = West and Central Africa, E&S Africa = East and South Africa, HHs = households

[1] Cups child^{-1} day^{-1}
[2] Proportion of children 6 to 23 months of age who consumed dairy in the past 24 hours
[3] mL capita^{-1} day^{-1} measured at household level
[4] Median over 3 years
[5] Difference between matched pairs of children, children from dairy HHs/consuming HH > children from rural HHs
[6] Analysis based on individual consumption by child, n=30

Hoorweg *et al.* (2000) compared HAZ and WAZ of children from households engaged in intensive dairy production and their clients in coastal Kenya with that of children from the general rural population. Average per capita dairy consumption, recorded at household level, was about 20-fold higher in producer/client households than in 'average' rural households, and analysis of matched child pairs from the two groups showed significantly better HAZ and WAZ scores in the former group.

Headey *et al.* (2018) analyzed Demographic Health Survey data on food consumption, including animal sourced foods (ASF), disaggregated by ASF groups (dairy, eggs, meat and fish), and child anthropometry from 112,553 children aged 6–23 months from 46 countries.

Using multivariate statistical models they found **significant associations between stunting and dairy consumption in children aged 18–23 months in three out of five world regions represented by the 46 countries**, namely Latin America and the Caribbean (-4.4% stunting in dairy consumers), South, Central and Eastern Asia (-4.8%), and Eastern and Southern Africa (-6.6%).

Kidoido and Korir (2015) used the Tanzania Living Standards Measurement Study-Integrated Surveys on Agriculture (LSMS-ISA) household panel data of 2008/2009 and 2010/2011 to investigate linkages between dairy consumption and child growth. They divided the dataset into low- (n=424) and high-income (n=425) households and estimated the effect of dairy consumption in each of the two strata using multivariate regression models. Age of mother and year were statistically significant determinants of HAZ and WAZ in both household groups while dairy consumption was significantly and positively related to HAZ (+0.13SD) and WAZ (+0.40SD) in the low-income household group. A positive relation between dairy consumption and HAZ and WAZ was also seen in high-income households, but the estimated effect was smaller and not statistically significant.

Synthesis: Table 3 summarizes the findings of all analyses of milk consumption and child growth presented in the papers included in the review. Sixteen of 17 comparisons of outcomes related to child height/length found a positive association with milk consumption ($p<0.01$), with one study not reporting the direction of impact. In 10 out of 18 comparisons the difference was significant at the 5% level in a two-sided test. Likewise, all comparisons related to child weight found a positive association with milk consumption ($p<0.01$) with 7 out of 12 differences being significant at the 5% level.

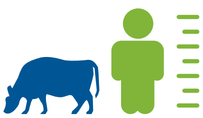
Table 3: Summary of results of analyses of the relationship between milk/dairy consumption and child growth

	Stunting/HAZ/height gain			WAZ/weight gain		
	Positive	p<0.10	p<0.05	Positive	p<0.10	p<0.05
Intervention	7[1]/8*	4/8	4/8	8/8**	5/8	5/8
Observational	9/9[2]**	6/10	6/10	3/3[2]ns	2/4	2/4
Total	**16/17****	**10/18**	**10/18**	**11/11****	**7/12**	**7/12**

^ p<0.1; * p<0.05; ** p<0.01; ns: p>0.1 (binomial distribution assuming no relationship, i.e. 50% chance of a possible result)

[1] One with 0 difference

[2] One unreported direction of impact



Cow / goat ownership and child growth

Intervention trials: Only two published studies evaluated the impact of providing households with dairy cattle (Rawlins *et al.* 2014 in Rwanda) or dairy and local goats (Kassa *et al.* 2003 in Ethiopia) on child growth (Table 4).

Table 4: Summary of evaluations of impact of programs providing households with cattle or goats on dairy consumption and child growth (the 'treatment' effect refers to the difference between the comparison groups and is not the result of regressions against milk consumption)

Study	Comparison	Age group	Estimated 'treatment' effect		
			Dairy consumption	% stunted / HAZ	% underweight / WAZ
Kassa *et al.* 2003 Ethiopia	Dairy/local goat vs. no goat	0 to 5y	+*[1]	-13.6%^	-16.3%*
Rawlins *et al.* 2014 Rwanda	Actual vs. prospective dairy cow beneficiary	0 to 5y	+**	0.54^	0.40ns

^ p<0.1; * p<0.05; ** p<0.01; ns: p>0.1

[1] Reported in Ayalew *et al.* 1999

Kassa *et al.* (2003) compared households that had received local or dairy goats at least 18 months prior to assessment to households that did not own goats. A crude comparison of the proportion of stunted and underweight children between goat recipient and non-recipient households carried out by the authors of this review showed a statistically significant (p<0.05) reduction in the proportion of underweight children and a reduction in stunting which approached statistical significance (p<0.1). This is in contradiction to Kassa *et al.*'s conclusion that "nutritional status of (woman and) children did not vary with participation in the project."

Rawlins *et al.* (2014) evaluated Heifer International's dairy cow ownership program in Rwanda using a non-randomized quasi-experimental design with a small sample of 43 children aged 0–59 months from beneficiary households and 56 children from households that had been assessed as being eligible beneficiaries but had not yet received a cow. They found that children from households who received a pregnant cow (high-productivity foreign breeds) at least 12 months prior to the survey had higher HAZ scores, a difference which approached statistical significance. The difference in WAZ score was also positive but smaller and not statistically significant.

Observational studies: Five observational studies examining the relationship between ownership of a cow and child growth were found in the literature (Table 5). Three of the five studies analyzed the relationship separately for children up to two years of age and children aged two to five years. One study, Nicholson *et al.* (2003), separately examined the impact of (dairy) cow ownership on child growth in coastal and highland areas of Kenya. In all instances in which milk consumption was reported (7 out of 9), it was significantly (p<0.05) higher in children/households owning cows than in comparison households.

Table 5: Summary of observational studies on dairy cow ownership, dairy consumption and child growth (the treatment effect refers to the difference between the comparison groups and is not the result of regressions against milk consumption)

Study	Comparison	Age group	Estimated 'treatment' effect			
			Dairy consumption	% Stunted	HAZ	WAZ
Choudhury & Headey 2017 Bangladesh	Lactating cow vs. no cow	0.5 to <2y	+**[1]	-10.4*	0.52**	--
		2 to <5y	nr	-5.9ns	0.04ns	--
Fierstein *et al.* 2017 Uganda	Nonnative cow vs. no nonnative cow - rural	0 to <2y	+**[1]	--	1.32**	--
		2 to <5y	+**[1]	--	0.58*	
	Nonnative cow vs. no nonnative cow - urban	0 to <2y	+ns	--	≈0.40ns	--
		2 to <5y	+ns	--	1.08*	
Hoddinott *et al.* 2015 Ethiopia	Cow vs. no cow	0.5 to 2y[2]	+**[1]	-5.5^	0.21^	0.08ns
		2 to 5y[2]	nr	-1.8ns	0.06ns	-0.01ns
		1 to 2y[3]	+**	-5.8^	0.23*	
Kabunga *et al.* 2017 Uganda	Improved vs. local cow	0 to 5y	+**	--	0.48^	0.10ns
Nicholson *et al.* . 2003 Kenya	Dairy & local vs. no cow - Coast	0 to <6y	+* (dairy cow vs. other 2)	--	1.10*	--
	Dairy & local vs. no cow – Highlands	0 to <5y	+*	--	0.29ns	--

^ p<0.1; * p<0.05; ** p<0.01; ns: p>0.1; nr: not reported

[1] Dairy consumption of children of respective age group, otherwise household consumption

[2] Agricultural growth program survey 2011

[3] Ethiopia 2000 demographic and health survey

RESULTS

All studies controlled for confounding by using multivariate regression analyses to capture household, demographic, maternal and other potentially confounding characteristics and/or by employing propensity score matching techniques.

In all four instances where it was recorded, the proportion of stunted children was lower in cow-owning households, approaching statistical significance in 0.5 to 2 year olds in the study by Hoddinott *et al.* (2015) and reaching statistical significance ($p<0.05$) in the study by Choudhury and Headey (2018). HAZ scores were significantly higher in cow-owning households than in comparison households in five of eleven comparisons, while approaching statistical significance in another two comparisons. In three of four analyses which stratified children into two age groups, the differences in body height were more pronounced in children below two years of age than in those above two years of age. Only two studies (Hoddinott *et al.* 2015 and Kabunga *et al.* 2017) analyzed the association between dairy cow ownership and WAZ but neither found a statistically significant relationship.

Choudhury and Headey (2018) distinguished between a control group of households that did not own cows, a treatment group that owned cows that had produced milk, and a placebo group of cow-owning households that had not produced milk in the past 12 months. They found significant differences in treatment and placebo coefficients in the 6–23 month, 6–17 month and 12–23 month age ranges, which suggests that it is milk production, not cow ownership per se, that enhances linear growth in early childhood. As a potential downside to household dairy production, they found a 21.7 percent decline in the rate of breastfeeding.

Synthesis: Table 6 summarizes the findings of all analyses of the relationship between (dairy) cow/goat ownership and child growth presented in the papers included in the review. All 14 comparisons of child length/height found a positive association ($p<0.01$), with the estimated effect significant at the 10% level in a two-sided test in 10 of the 14 comparisons (i.e. the difference would be significant at the 5% level in a more appropriate one-sided test for significance). Although 4 out of 5 comparisons related to child weight found a positive association, the estimated effect was generally smaller than for height and statistically significant in one case only (0 to 5 year old children).

Table 6: Summary of results of analyses of the relationship between (dairy) cow / goat ownership and child growth

	HAZ/stunting			WAZ/underweight		
	Positive	p<0.10	p<0.05	Positive	p<0.10	p<0.05
Intervention	2/2ns	2/2	0/2	2/2ns	1/2	1/2
Observational	12/12**	8/12	6/12	2/3ns	0/3	0/3
Total	**14/14****	**10/14**	**6/14**	**4/5ns**	**1/5**	**1/5**

^ p<0.1; * p<0.05; ** p<0.01; ns: p>0.1 (binomial distribution assuming no relationship, i.e. 50% chance of a positive result)

DISCUSSION

DISCUSSION

This review contains ten studies published since a previous review on dairy and nutrition by Iannotti *et al.* (2013), which substantially expands the evidence base. Unfortunately, with the exception of one study from Bangladesh, geographic coverage on the impact of dairy cow/goat ownership, i.e. dairy production on child growth remains limited to eastern Africa. Observational studies on the relationship between dairy consumption and child growth almost exclusively stem from eastern Africa as well; the multi-country/multi-region study of Headey *et al.* (2018) being the only one covering other regions. (Bao *et al.* 2018 cover Southeast Asian countries but do not control for potential confounders in their analysis[6].) By contrast, six of the eight eligible dairy supplementation trials were carried out in Asia. External validity might thus remain a concern, particularly for findings relating to the ownership of dairy animals and child growth.

Milk consumption and child growth

Both observational and intervention studies cited in this paper may have been affected by methodological issues inherent in all nutrition trials conducted on subjects in a freely living environment. Observational studies widely use 24-hour recalls of food consumption, which may not fully capture regular consumption of dairy products. Some children who consumed milk during the 24-hour period assessed via the diet recall may not be regular consumers of milk and vice versa, leading to potential misclassification and attenuation biases[7]. Intervention studies may also suffer from substitution effects (e.g. tendency of parents not to give their children breakfast or lunch because they are getting food at school), sharing treatment products with control subjects, etc., attenuating the relation between milk and child growth. These are pitfalls that often occur in nutritional studies when total diet is not fully controlled. Furthermore, for several studies, the low number of subjects and/or the short duration severely limited the likelihood of detecting a significant positive relation between dairy consumption and child growth.

Despite the above shortcomings, virtually all analyses, both from experimental and observational studies, **found a positive association between milk/dairy consumption and child growth.**

Additionally, results of the randomized controlled supplementation trials revealed a dose-response relationship between dairy consumption and child growth. These findings provide strong evidence that the consumption of milk/dairy products per se improves child growth.

However, the effect of milk on child growth appears to be context specific as demonstrated by the analyses of Headey *et al.* (2018), who do not find a significant relationship in the

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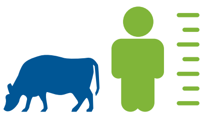
[6] The prevalence of stunting and underweight was lower in children who consumed dairy on a daily basis (10.0% and 12.0%, respectively) compared to children who did not use dairy (21.4% and 18.0%, respectively) ($p < 0.05$).

[7] Biasing of the regression slope towards zero, i.e. the underestimation of its absolute value, caused by errors in the independent variable.

Near East/North Africa nor West and Central Africa despite the high statistical power of their study. Grillenberger *et al.* (2003) note that the effect of milk supplementation appeared to be stronger in children with lower initial HAZ scores, and Kidoido and Korir (2015) find a larger impact of milk consumption on children from low-income households. These indications of effect-modification[8] are not surprising as the outcome of any nutritional intervention is contingent upon the overall dietary intake of the study population.



Cow/goat ownership and child growth

It is widely acknowledged that in low-income settings household ownership of non native/dairy cattle acts as a proxy for household socioeconomic status, which implies that these households likely have greater access to high(er)-quality foods, safe water, health care, education, etc. However, cattle ownership remained a significant predictor of child height even after controlling for potential confounders. Milk consumption was consistently higher in households owning (dairy) cattle/goats than in the comparison group. Iannotti and Lesorogol (2014b) report that livestock ownership rather than income was the key determinant of household milk consumption, while Hoddinott *et al.* (2015) found that cow ownership was not significantly associated with more consumption of other high-value nutrient-dense food. It thus is likely that at least part of the enhanced growth of children from dairy households is due to higher milk intake from own production.

As seen with the effect of milk consumption, the impact of dairy animal ownership on child growth appears to be subject to effect modification. For instance, improvement in HAZ scores appear particularly marked in children in the 0.5 to <2-year age group compared to 2 to <5-year-old children. Also, animal ownership appears to have a stronger effect on child growth in situations where dairy markets are underdeveloped and in poorer households (Hoddinott *et al.* 2015).

Implications for dairy development and SDG2

The literature reviewed provides strong evidence that in **rural low-income settings household milk production increases household milk consumption, and that increased milk consumption results in improved child linear growth and reduced stunting.**

Dairy development can thus be considered a useful instrument in the quest to achieve SDG2, while simultaneously supporting SDG1 (reducing poverty) (FAO, GDP and IFCN 2018). That said, further rigorous studies are needed to better understand the types and quantities of dairy products suitable for different regions and circumstances, and the best means to enable access to them for poor communities and households (Grace *et al.* 2018).

[8] Effect modification is a phenomenon in which the 'treatment' (or exposure) has a different impact in different circumstances.

DISCUSSION

Dairy development may be approached by: (i) expanding cow ownership, (ii) improving cow productivity by providing access to required inputs and services, and (iii) facilitation of milk marketing. These approaches are not mutually exclusive but, in many circumstances, expanding cow ownership may be limited by natural resource constraints. Improving cow productivity has the dual advantage of increasing milk availability and reducing the environmental impact per kg of milk. In order to benefit the larger population, however, marketing channels need to be established.

Development of milk markets not only benefits consumers but has also been shown to generate substantial employment (Kumar *et al.* 2010, Omore et al. 2005, USAID 2014).

Employment generation should be considered an additional benefit in view of the expanding labor force in many low- and middle-income countries. However, given milk is a growth medium for a variety of pathogens to which children may be particularly vulnerable, appropriate food safety systems need to be put in place to support public health when expanding the dairy sector.

In their review of the effectiveness of agricultural interventions in improving nutrition outcomes, Berti *et al.* (2003) conclude that concomitant nutrition education is of central importance for achieving nutrition improvement. To maximize its impact towards achieving SDG2, dairy development should be accompanied by nutrition education of caregivers and other members of the household and the communities at large (e.g. men and grand mothers) so as to ensure that milk is provided in the most critical phase of childhood, namely in the 0.5 to 2 year age group, without reducing the frequency of breast feeding. Nutrition messages should also give due consideration to the nutritional requirements of pregnant women as low birth weight is one of the leading risk factors for stunting in developing countries (Danaei *et al.* 2016).

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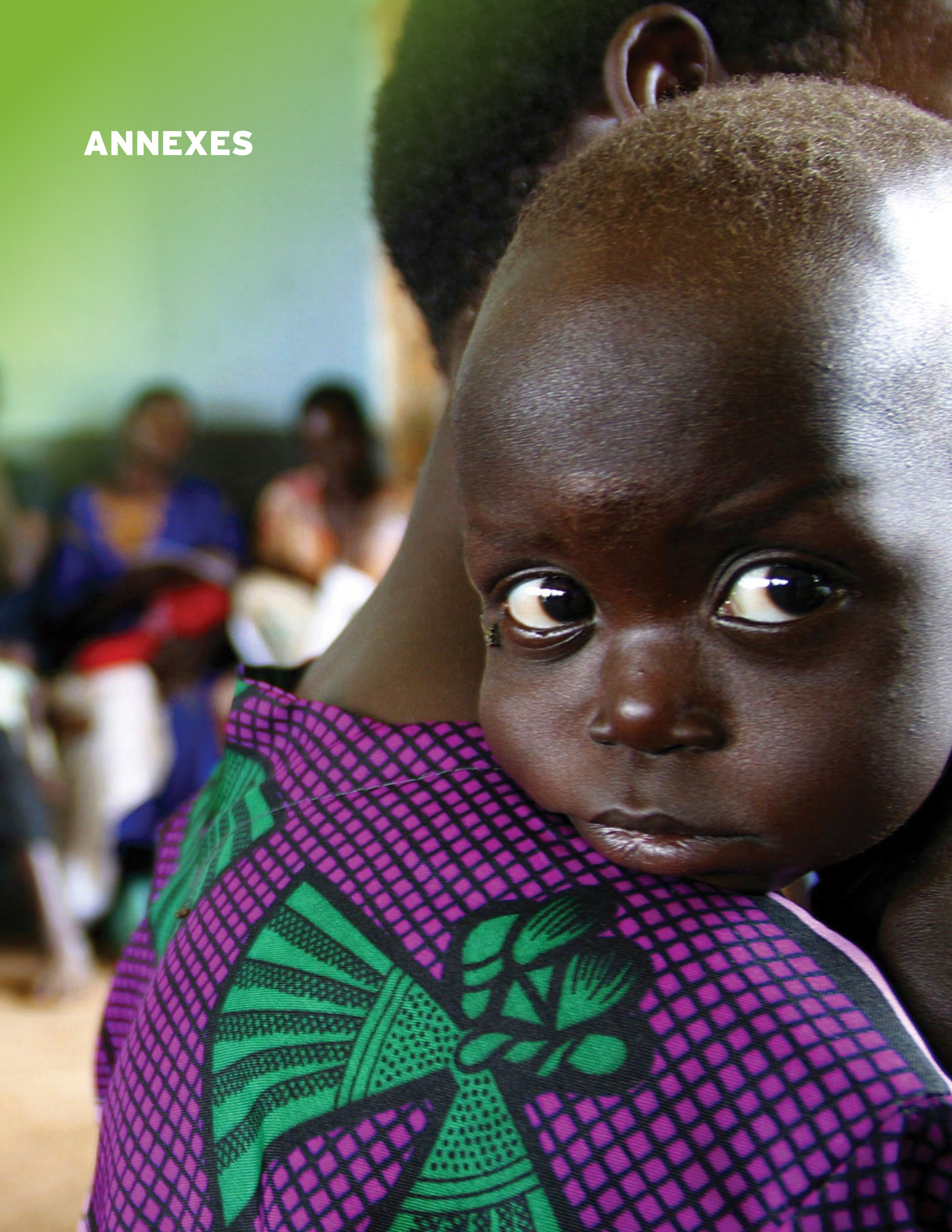
ANNEXES



ANNEX 1: FINDINGS OF PREVIOUS REVIEWS ON DAIRY AND CHILD NUTRITION

Milk/dairy consumption and child growth

Four reviews carried out between 2006 and 2013 assessed the published evidence linking milk/dairy consumption to child growth (Table A1.1). Three of the reviews focused specifically on dairy while in one review (Allen and Dror 2011/Dror and Allen 2011) the effect of 'dairy' consumption was assessed within the wider context of animal-sourced food. The most comprehensive review of studies on the impact of milk consumption on linear growth was undertaken by Hoppe *et al.* (2006), who reviewed studies undertaken in industrialized and developing countries dating back as far as 1928. De Beer (2012) limited his review to controlled supplementation trials while Iannotti *et al.* (2013) restricted their review to 'milk and dairy programs' implemented in developing countries after 1980. The latter included school-based milk programs, fortified milk programs, milk powder and blended foods and dairy production and agriculture programs.

All four reviews conclude that published results on the association between milk intake and height suggest that cow's milk has a positive effect on linear growth. The strength of the evidence for this association is rated as moderate in three of the four reviews (Allen and Dror, 2011, de Beer, 2012, and Iannotti *et al.*, 2013). The strength of the cumulative evidence was rated as moderate because vitamins and micronutrients were often provided in addition to the milk supplement and some intervention studies were not randomized. Based on a larger set of reviewed studies, which comprise early intervention trials and observational studies showing strong positive association between the consumption of cow's milk and linear growth in children in well-nourished populations, **Hoppe** *et al.* **(2006) conclude that dairy has a growth-stimulating effect even in situations where the nutrient intake is adequate.** They suggest that this conclusion is supported by studies that show milk intake stimulates circulating insulin-like growth factor (IGF)-I, which suggests that at least part of the growth-stimulating effects of milk occur through the stimulation of IGFs.

Table A1.1: Summary of reviews assessing the relationship between milk/dairy consumption and child growth (height and/or weight)

Review	'Interventions' & outcome(s)	Geographic scope & period	Studies	Conclusion(s)
Hoppe *et al.* 2006	Milk consumption & linear growth (and serum IGF)	Global; 1928 onward	44[1]	Milk has a growth-stimulating effect even in situations where the nutrient intake is adequate.
Allen & Dror 2011 / Dror & Allen 2011	ASF intake & child growth, development and health	LICs[2]; 1970 onward	5[3]	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.
de Beer 2012	Controlled trials of supplementation of normal diet with dairy and height gain	Global; 1926 onward	12	Moderate quality evidence that dairy product supplementation stimulates linear growth.
Iannotti *et al.* 2013	Milk programs & child nutrition	Developing countries; 1980 onward	24, of which 6 school milk	Studies suggest (positive) impacts (of school milk progs.) on child growth

[1] Studies related to growth in preschool and school children
[2] Includes 1 study from NL comparing macrobiotic to non-macrobiotic diets
[3] Studies assessing specific impact of milk, 2 observational studies & 3 intervention trials

Agricultural interventions and child growth

The impact of dairy development, i.e. support to enhancement of milk production, on child growth has mostly been reviewed within the context of broader reviews of nutrition outcomes of agricultural interventions (Table A1.2). The available reviews assessed a broad array of interventions and outcomes, but most evaluations only examined intermediary outcomes of production, sometimes consumption but rarely child anthropometry.

The reviewed studies generally reported a positive impact on dietary intake but improved diet did not always coincide with improvements in biochemical/clinical indicators. **All reviews conclude that there is little evidence that the assessed agricultural interventions had a positive impact on child anthropometry**. However, as Masset *et al.* (2012) state, these disappointing results should not be interpreted as evidence of the absence of an effect. Many of the studies reviewed included small samples of children. Masset *et al.* (2012) estimated that "*an intervention effect of 10% would be detected with a probability of only 15%. On the basis of this analysis, the absence of any reported statistically significant effect of agricultural interventions on nutritional status found by this review, as well as by other reviews that preceded this one, cannot be attributed with certainty to lack of efficacy. Rather, the lack of power of the studies reviewed could have prevented the identification of any effect*" (Masset *et al.* 2012).

ANNEX 1: FINDINGS OF PREVIOUS REVIEWS ON DAIRY AND CHILD NUTRITION

Table A1.2: Summary of reviews assessing the relationship between agricultural interventions, including dairy development, and nutritional outcomes

Review	'Interventions' & outcome(s)	Geographic scope & period	Studies	Conclusion(s)
Berti *et al.* 2004	Agriculture & diet, morbidity, child nutritional status	Developing countries; 1985 to 2001	30, of which 4 'dairy'	Agriculture interventions had mixed results in terms of improving nutritional status in participating households.
Leroy & Frongillo 2007	Animal production & income / expenditure, diet, child nutritional status	Developing countries; 1987 to 2003	15, of which 5 'dairy'	Insufficient evidence to answer whether the promotion of animal production is an effective means to alleviate under-nutrition.
Masset *et al.* 2012	Agriculture & income, diet, child nutritional status	LICs; 1990 to 2010	23, of which 1 'dairy'	Very little evidence of a positive effect on the prevalence of stunting, wasting, and underweight among children aged under 5.
Girard *et al.* 2012	Agriculture & maternal and child nutrition and health	LMICs; 1990 to 2011	32[1], of which 1 'dairy'	Summary estimates for effects on stunting, underweight and wasting were not significant.
Iannotti *et al.* 2013	Dairy development & diet, child nutritional status	Developing countries; 1980 onward	24, of which 7 'dairy production'	Dairy programs looked primarily at diet. Insufficient evidence for linking DD to child nutritional status.

[1] Reporting on child outcomes

ANNEX 2: NUMBER OF PUBLICATIONS RETURNED BY SEARCH STRING

Table A2.1: Number of titles returned by different combinations of search strings

Key search terms	Milk	Dairy	Dairy animals
Food security	393	362	136
Food insecurity	103	79	8
Malnutrition	668	163	26
Stunting	185	49	14
Wasting	1,843	3,174	742
Low height for age	354	224	54
Low weight for age	2,295	224	335
Underweight	118	41	3
Body mass index	1,471	996	71
BMI	980	665	52
Dietary energy supply	8	8	4
DES	151	76	30
Nutritional status	192	503	
Undernourishment	11	3	
Undernutrition	281	118	
Adequate nutrition	71	26	
Adequate growth	659	261	
Linear growth	136	33	
TOTAL	9,919	7,005	1,475

ANNEX 3: MAIN CHARACTERISTICS AND RESULTS OF STUDIES INCLUDED IN THE REVIEW

Table A3.1: Main characteristics and results of intervention trials on dairy/milk supplementation and child growth

Study	Country	Age group (y)	Sex	Intervention group (IG) supplement	Amount	Dairy protein (g)[1]	Frequency
Supplementation with milk protein only							
Du *et al.* 2004	China	10	F	UHT Milk + Ca[a]	330mL	10.6	Every school day[b]
Grillenberger *et al.* 2003	Kenya	6 to 14	M+F	UHT Milk	ca. 190mL	6.1	Every school day
He *et al.* 2005	China	3 to 5	M+F	Yoghurt	125g	3.8	5d/wk
Ihab *et al.* 2014	Indonesia	2 to 10	M+F	Milk	500mL	16.0	Daily
Lien *et al.* 2009	Vietnam	7 to 8	M+F	Milk	500mL	16.0	6d/wk
Supplementation with milk protein, vitamins and minerals							
Bhandari *et al.* 2001	India	0.3 to 1	M+F	Milk-based cereal[d]	8g protein	8.0	Daily
Hall *et al.* 2007	Vietnam	6 to 9	M+F	UHT milk[f]	200mL	6.4	5d/wk[g]
Lee *et al.* 2018	Ghana	6 to 9	M+F	SMP[h]	8.8g milk protein	8.8	Every school day[i]

[1] Dairy protein assumed as 32g/L milk
[2] Dairy protein per supplement multiplied by days supplement provided if stated in the paper, otherwise by frequency of supplementation and duration of the trial
^ p<0.10, * p<0.05, ** p<0.01
[a] Ca added to provide same amount as in fresh milk (1,120mg/L)
[b] Average of 144ml/day over trial period
[c] 18 months of school
[d] Plus counseling on use of supplement
[e] Visitation group
[f] Plus Vit A&D and fortified biscuit
[g] Total of 173 days
[h] Plus micronutrients
[i] Mean of 115 days of consumption
[j] Placebo controlled, double blind
[k] HAZ
[l] WAZ

Duration (m)	Total dairy protein received (g)[2]	Randomization	Group	N final	Baseline height (cm)	Baseline weight (kg)	Height change (cm)	Weight change (kg)
24	5,879	By school	IG	207	140.4	33.9	13.4**	11.6**
			CG	234	140.7	33.4	12.2	10.1
23[c]	2,392	By school	IG	132	115.5	19.9	10.29	3.86*
			CG	117	115.5	20.0	9.95	3.49
9	745	Y	IG	201	101.0	15.3	5.43*	1.42*
			CG	201	100.8	15.6	5.24	1.20
6	2,928	Y	IG	30	114.7	19.1	3.6*	1.7
			CG	30	113.8	18.5	2.6	0.9
6	2,510	Within school	IG	151	117.4	18.8	3.6	1.5
			CG	143	116.8	19.0	3.2	1.1
8	1,952	Y	IG	87	58.2	5.0	10.3	2.09*
			CG[e]	91	58.4	5.2	9.9	1.84
17	1,107	By school	IG	360	112.1	17.9	8.15**	3.19**
			CG	720	111.7	17.8	7.88	2.95
9	1,012	Y[j]	IG	236	-0.8[k]	-0.9[l]	0.02	0.07
			CG	237	-0.8	-1.0	0.02	0.03

ANNEX 3: MAIN CHARACTERISTICS AND RESULTS OF STUDIES INCLUDED IN THE REVIEW

Table A3.2: Main characteristics and results of observational studies on milk consumption and child growth

Study	Country	Study type	Data source	Age group (y)	Stratum / comparison	Nr. Observations[1]	Milk consumption
Fratkin *et al.* 2004	Kenya	Longitudinal (3y)	Own surveys	0 to 9[a]		5,535[b]	0.4 to 3.6[c]
Headey *et al.* 2018	46	Cross-sectional	DHS[e]	0.5 to <2	LAC[f]	6,626	57.7[g]
					NENA	3,544	64.9
					SCE-Asia	6,881	38.4
					WC-Africa	9,314	20.8
					ES-Africa	6,625	18.7
Hoorweg *et al.* 2009	Kenya	Cross-sectional	Own survey	0.5 to <5	Dairy farmers	30	200[h]
					Their customers	24	249
					Rural hhs	86	11
Iannotti & Lesorogol 2014	Kenya	Longitudinal (10y)	Own surveys[j]	0 to 2		33	260 to 310[k]
				3 to 5		42	
				6 to 8		63	
				9 to11		34	
Kidoido *et al.* 2015	Tanzania	Cross-sectional	LSMS-ISAI	0 to 6	Low income dairy hhs	1,662	33[m]
					High income dairy hhs	1,623	41

[1] Children with anthropometric measurements
^ p<0.10, * p<0.05, ** p<0.01, ns = p>0.10
[a] <6y at start of study
[b] Repeat measures from 488 children
[c] Cups/child/day (graphic representation)
[d] Reduction in stunting probability per cup per day
[e] National demographic and health survey
[f] Latin America & the Caribbean (LAC), Near East & North Africa (NENA), South, Central & East Asia (SCE-Asia), West & Central Africa (WC-Africa), East & South Africa (ES-Africa)
[g] Proportion of 6 to 23 month old children consuming milk in past 24 hours
[h] mL/consumer unit (2,960kcal)/day
[i] % of international reference value, 51 matched pairs of children, paired t-test
[j] 3 panel surveys of 200 households (2000, 2005 and 2010), child anthropometry and diet from a cross-section of 55 hhs in 2012
[k] Median mL/adult equivalent/day over time
[l] Living Standards Measurement Study-Integrated Surveys on Agriculture
[m] mL/person/day

% stunted	ATT	HAZ	ATT	WAZ	ATT	Control for confounding
	-0.15[d] **	-0.4 to -2.0		-0.6 to -2.1		Multivariate generalized estimating equations
23.6	-0.044**					Multivariate statistical models saturated with control variables
25.8	-0.002ns					
37.1	-0.048**					
32.5	-0.007ns					
37.3	-0.066**					
13 to 23		93.9[i]*		84.7[i]**		Matching pairs of children for household income and age group
33		92.3		79.4		
41.9		-1.49	ns	-1.32	ns	OLS regression with covariates
22.0		-1.26		-1.31		
15.8		-0.56		-1.38		
9.1		-0.74		-1.63		
		-1.70	0.13**	0.08	0.40**	Multivariate regression models with covariates
		-0.08	0.09	0.39	0.06	

ANNEX 3: MAIN CHARACTERISTICS AND RESULTS OF STUDIES INCLUDED IN THE REVIEW

Table A3.3: Main characteristics and results of intervention trials on effect of dairy cattle / goats on child growth

Study	Country	Data source	Age group (y)	Group	Nr. Observations[1]	Milk comsumption
Kassa *et al.* 2003	Ethiopia	Own survey	0 to <5	Goat (dairy/local)	102	4.8[a]**
				No goat	71	2.5
Rawlins *et al.* 2014	Rwanda	Own survey	0 to 5	Dairy cow	43	5.8[c]
				Prospectives[b]	56	

[1] Children with anthropometric measurements

^ p<0.10, * p<0.05, ** p<0.01

[a] Times per week children consumed milk (from Ayalew *et al.* 1999)

[b] Households that were considered eligible to receive a cow but kept on the waiting list

[c] L milk & yoghurt consumed per person per month

[d] Average treatment effect estimated using propensity score matching (PSM) (10.9 additional L milk&yoghurt/person/month). Estimated effect using Tobit regression: 9.3L**

[e] Average treatment effect estimated using seemingly unrelated regression (SUR) with a set of control variables

ATT	% stunted	HAZ	ATT	% underweight	WAZ	ATT
	34.3^			34.3*		
	47.9			50.7		
10.9[d]**	22.4	-1.28	0.54[d]^	9.2	-0.72	0.40[e]

ANNEX 3: MAIN CHARACTERISTICS AND RESULTS OF STUDIES INCLUDED IN THE REVIEW

Table A3.4: Main characteristics and results of observational studies of the effect of dairy cattle/goats on child growth

Study	Country	Study type	Data source	Age group (y)	Comparison	Nr. Observations[1]	Milk consumption
Choudhury & Headey 2017	Bangladesh	Cross-sectional	BIHS[a]	0.5 to <2	Lactating cow	223	0.14[b]**
					Non-lact. cow	128	-0.02[b]
					No cow	1,245	
				2 to <5	Lactating cow	2,384	
					Non-lact. cow		
					No cow		
Fierstein *et al.* 2017	Uganda	Cross-sectional	UDHS[d], Rural sample	0 to <2	Non-native cattle	14	80.2[e]**
					No non-native cattle	709	24.6
				2 to <5	Non-native cattle	28	79.2**
					No Non-native cattle	890	17.8
			Urban sample	0 to <2	Non-native cattle	10	73.2
					No Non-native cattle	192	55.4
				2 to <5	Non-native cattle	11	53.2
					No Non-native cattle	216	35.5
Hoddinott *et al.* 2015	Ethiopia	Cross-sectional	AGPS[f]	0.5 to <2	Cow owners	1,590	1.48[g]**
					Non-owners		
				2 to 5	Cow owners	3,092	
					Non-owners		
		Cross-sectional	EDHS[m]	1 to 2	Cow owners	1,867	28[n]**
					Non-owners		
Kabunga *et al.* 2017	Uganda	Cross-sectional	NPS[i]	0.5 to 5	Improved dairy cow	108	66.2[j]*
					Local dairy cow	572	27.0
Nicholson *et al.* 2003	Kenya	Cross-sectional	Own survey, Coast	0 to <6	Dairy cow	53	0.97[k]*
					Local cow	28	0.35
					No cow	70	0.37
			Highlands	0 to <5	Dairy cow	127	6.45[k]*
					Local cow	19	2.24
					No cow	99	1.84

[1] Children with anthropometric measurements

^ p<0.10, * p<0.05, ** p<0.01

[a] Bangladesh 2011 & 2015 integrated household survey

[b] Increase in probability of milk consumption by 6 to 23 month old children vs children from no-cow households

[c] Compared to non-cow owning households

[d] Uganda 2011 demographic and health survey

[e] Probability of child milk consumption in past 24 hours

[f] Agricultural growth program survey

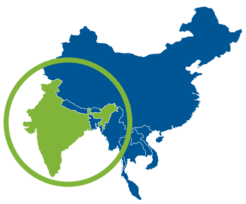
[g] Marginal increase in days milk or milk products are consumed by child

% stunted	ATT	HAZ	ATT	WAZ	ATT	Control for confounding
34.0	-10.4[c]*	-1.37	0.52[c]**			Multivariate regression models with a set of socio-economic controls, dummies for child gender and age and district fixed effects.
	-8.0[c]		0.16[c]			
	-5.9		0.04			
	-4.8		0.17			
6.0		0.2*	1.32**			Weighted multivariable linear regression with six categories of variables, which included WASH, child, maternal, household, geographic, and dietary characteristics, as potential confounders.
28.0		-1.1				
23.8		-1.2*	0.58*			
42.7		-1.9				
0.0**		-0.4	=0.40			
24.0		-0.8				
0.0		-0.1	1.08*			
15.7		-1.0				
47.0	-5.5[h]^	-1.74	0.21^		0.08	Least squares regression controlling for child, maternal, household and regional effects.
	-1.8		0.06		-0.01	
	-5.8^		0.23*			
		-0.95	0.48^	-0.55	0.10	Propensity score matching for child, maternal, household and geographic effects.
		-1.43		-0.65		
37.7		-1.57[l]*	1.10 [l]*			Multivariate regression models controlling for child, household, and head of household characteristics.
35.7		-1.01[l]*				
54.3		-2.05				
34.3		-1.35[l]*	0.29 [l]			
29.2		-1.24				
44.5		-1.71				

[h] Percentage decrease in stunting probability
[i] Uganda 2009/10 national panel survey
[j] L/person/year (app. 180 and 74 mL/day)
[k] L/adult equivalent/week, dairy cow significantly different from 'local' and 'no cow'.
[l] Compared to 'no cow' households
[m] Ethiopia 2000 demographic health survey
[n] Percent increase in probability of daily milk consumption

ANNEX 4: ABSTRACTS OF SELECTED PAPERS

A.4.1: MILK/DAIRY SUPPLEMENTATION AND CHILD GROWTH – INTERVENTION TRIALS



Bhandari N *et al.*, 2001. Food supplementation with encouragement to feed it to infants from 4 to 12 months of age has a small impact on weight gain

It is unclear whether a substantial decline in malnutrition among infants in developing countries can be achieved by increasing food availability and nutrition counseling without concurrent morbidity-reducing interventions. The study was designed to determine whether provision of generous amounts of a micronutrient-fortified food supplement supported by counseling or nutritional counseling alone would significantly improve physical growth between 4 and 12 mo of age. In a controlled trial, 418 infants 4 mo of age were individually randomized to one of the four groups and followed until 12 mo of age. The first group received a **milk-based cereal and nutritional counseling**; the second group monthly nutritional counseling alone. To control for the effect of twice-weekly home visits for morbidity ascertainment, similar visits were made in one of the control groups (visitation group); the fourth group received no intervention. The median energy intake from nonbreast milk sources was higher in the food supplementation group than in the visitation group by 1212 kJ at 26 wk (P<0.001), 1739 kJ at 38 wk (P<0.001) and 2257 kJ at 52 wk (P<0.001). **The food supplementation infants gained 250 g (95% confidence interval: 20–480 g) more weight than did the visitation group. The difference in the mean increment in length during the study was 0.4 cm (95% confidence interval: -0.1–0.9 cm)**. The nutritional counseling group had higher energy intakes ranging from 280 to 752 kJ at different ages (P<0.05 at all ages) but no significant benefit on weight and length increments. Methods to enhance the impact of these interventions need to be identified.

Du X *et al.* 2004. School-milk intervention trial enhances growth and bone mineral accretion in Chinese girls aged 10–12 years in Beijing

A 2-year milk intervention trial was carried out with 757 girls, aged 10 years, from nine primary schools in Beijing (April 1999 – March 2001). Schools were randomised into three groups: group 1,238 girls consumed a carton of 330 ml milk fortified with Ca on school days over the study period; group 2,260 girls received the same quantity of milk additionally fortified with 5 or 8mg cholecalciferol; group 3,259 control girls. Anthropometric and bone mineralisation measurements, as well as dietary, health and physical-activity data, were collected at baseline and after 12 and 24 months of the trial. **Over the 2-year period the consumption of this milk, with or without added cholecalciferol, led to significant increases in the changes in height (≥0·6 %), sitting height (≥0·8 %), body weight (≥2·9 %)**, and (size-adjusted) total-body bone mineral content (≥1·2%) and bone mineral density (≥3·2 %). Those subjects receiving additional cholecalciferol compared with those receiving the milk without added 25-hydoxycholecalciferol had significantly greater increases in the change in (size-adjusted) total-body bone mineral content (2.4 v. 1.2%) and bone mineral density (5.5 v.

3.2 %). The milk fortified with cholecalciferol significantly improved vitamin D status at the end of the trial compared with the milk alone or control groups. It is concluded that an increase in milk consumption, e.g. by means of school milk programmes, would improve bone growth during adolescence, particularly when Ca intake and vitamin D status are low.

Grillenberger M *et al.* 2003. Food Supplements Have a Positive Impact on Weight Gain and the Addition of Animal-Source Foods Increases Lean Body Mass of Kenyan Schoolchildren

Observational studies of dietary patterns and growth and studies with milk supplementation have shown that children consuming diets containing animal-source foods grow better. This study evaluates the growth of 544 Kenyan schoolchildren (median age 7.1 y) after 23 mo of food supplementation with a meat, milk or energy supplement (≈1255 kJ) compared to a control group without a supplement. Multivariate analyses controlled for covariates compared gain in weight, height, weight-for-height Z-score (WHZ), height-for-age Z-score (HAZ), midupper-arm circumference, triceps and subscapular skinfolds, mid-upper-arm muscle and mid-upper-arm fat area. Children in each of the supplementation groups gained ≈0.4 kg (10%) more weight than children in the Control group. Children in the Meat, Milk and Energy groups gained 0.33, 0.19 and 0.27 cm more, respectively, in mid-upperarm circumference than children in the Control group. Children who received the Meat supplement gained 30–80% more mid-upper-arm muscle area than children in the other groups, and children who received the milk supplement gained 40% more mid-upper-arm muscle area than children who did not receive a supplement. **No statistically significant overall effects of supplementation were found on height, HAZ, WHZ or measures of body fat. A positive effect of the milk supplement on height gain could be seen in the subgroup of children with a lower baseline HAZ (≤-1.4)**. The results indicate that food supplements had a positive impact on weight gain in the study children and that the addition of meat increased their lean body mass.

Hall A *et al.* 2007. An evaluation of the impact of a school nutrition programme in Vietnam

Objective: To evaluate the effectiveness of a school nutrition programme on the weight gain and growth of Vietnamese schoolchildren. **Design:** A proximate cluster evaluation of children in seven schools, in which fortified milk and biscuits supplying 300 kcal of energy were being given on school days, compared with children in 14 nearby schools with no feeding. All children were dewormed. **Setting:** Twenty-one primary schools in Dong Thap Province, Vietnam. **Subjects:** A cohort of 1080 children in grade 1 of 21 primary schools, and a cross-sectional interview of 400 children in grade 3. **Results:** The programme gave children the equivalent of 90 kcal day^{-1} over 17 months. t-Tests showed **a small but statistically significant difference between groups in their average gain in weight and height: 3.19 versus 2.95 kg (P < 0.001) and 8.15 versus 7.88 cm (P = 0.008)**. A multiple-level model showed that the programme was statistically significant after controlling for clustering of children in schools, sex, age and initial underweight (P = 0.024). A significant impact on height was also seen in a regression model, but not when controlling for school. The most undernourished children tended to gain the least weight. There was no evidence of substitution. **Conclusion:** The programme had a small but significant effect on weight gain, but the most undernourished children benefited the least. Methods need to be developed to target them. This design may offer a means of estimating the impact of school feeding on growth in other programme settings.

He M *et al.* 2005. Effects of yogurt supplementation on the growth of preschool children in Beijing suburbs

Objective: To investigate the effect of yogurt supplementation on the growth of preschool children in Beijing suburbs. **Methods:** Four hundred and two preschool children (217 males, 185 females), aged 3-5 years, whose height for age and/or weight for age were less than the reference level, were selected as subjects from 7 kindergartens in Beijing Fangshan District. The subjects were divided randomly into control group (CG, 201) and yogurt supplemented group (YG, 201). Each subject in YG was given one serving of yogurt (125 g) for 5 days a week from March to December in 2001, while nothing additional was provided to CG. All subjects kept their usual diet during the study. Anthropometry (body height and weight and upper-arm circumference) and the bone mineral density (BMD) of forearm were measured every 3 months. Disease status and dietary intake were also recorded and assessed. **Results:** The intake of calcium, zinc, and vitamin B2 in YG was significantly higher than that in CG. The incidence and duration of upper-respiratory infection and diarrhea of children in YG were significantly less than those in CG. **The height gain of children in YG was significantly higher than that in CG after yogurt was supplemented for 3, 6, and 9 months (P<0.05) (1.90+/-0.49 cm vs 1.77+/-0.54 cm, 3.83+/-0.57 cm vs 3.64+/-0.66 cm and 5.43+/-0.69 cm vs 5.24+/-0.76 cm, respectively). The weight gain of children in YG was significantly higher than that in CG after yogurt was supplemented for 3, 6, and 9 months (P<0.05) (0.70+/-0.43 kg vs 0.49+/-0.35 kg, 0.98+/-0.62 kg vs 0.80+/-0.60 kg and 1.42+/-0.76 kg vs 1.20+/-0.67 kg, respectively)**. The BMD of children in YG was significantly higher than that in CG after yogurt was supplemented for 9 months (P<0.05) (0.415+/-0.058 g/cm2 vs 0.400+/-0.065 g/cm2). **Conclusion:** Yogurt is beneficial to the improvement of calcium, zinc, and vitamin B2 intake, the decreasing of the incidence and duration of upper-respiratory infection and diarrhea, and the promotion of the health and the growth and development of preschool children.

Ihab AN *et al.* 2014. The Impact of Animal-Source food (ASF) on the Growth of Malnourished Children in Bachok, Kelantan: Randomized Controlled Intervention Trial

Objective: The aim of this study was to evaluate the effect of Animal-Source Food on the growth of Malaysian malnourished children in Bachok, Kelantan. **Method:** A six months Animal-Source Food (ASF) intervention trial was carried out with 90 malnourished children, aged 2-10 years, from food insecure households in Bachok, Malaysian. Children were randomized into three groups: Milk Group (n=30) consumed two boxes of 250 ml milk daily over the study period, Egg Group (n=30) received two eggs daily and Control Group (n=30) children who did not receive any food intervention. Anthropometric data were collected at baseline, after 3 and 6 months of the intervention trial. **Results: Over the 6 months study period there was a significant increase in children's height for all groups (Milk Group; 3.62 cm; $p<0.001$, Egg Group; 3.51 cm, $p<0.001$, Control Group; 2.55 cm, $p<0.001$), weight (Milk Group; 1.72 kg; $p<0.001$, Egg Group; 1.67 kg, $p<0.001$, Control Group; 0.87 kg. $p<0.001$)**, and mid upper arm circumference (MUAC) (Milk Group; 0.80 cm; $p<0.001$, Egg Group; 0.78 cm, $p<0.001$, Control Group; 0.31 cm; $p=0.023$). **Conclusion**: The impact of the intervention was positive but the effectiveness was not large enough to define as success of the intervention program.

Lee R*et al.* 2018. Milk Powder Added to a School Meal Increases Cognitive Test Scores in Ghanaian Children

Background: The inclusion of milk in school feeding is accepted as good nutritional practice, but specific benefits remain uncertain. **Objective:** The objective was to determine whether consumption of 8.8 g milk protein/d given as milk powder with a multiple micronutrient–enriched porridge resulted in greater increases in linear growth and Cambridge Neuropsychological Test Automated Battery (CANTAB) scores in Ghanaian schoolchildren when compared with 1 of 3 control groups. **Methods:** A randomized, double-blind, placebo-controlled clinical trial in healthy children aged 6–9 y was conducted comparing 8.8 g milk protein/d with 4.4 g milk protein/d or 4.4 g milk protein + 4.4 g rice protein/d (isonitrogenous, half of the protein from milk and half from rice) or a non-nitrogenous placebo. Primary outcomes were changes in length after 9 mo and CANTAB scores after 4.5 mo; secondary outcomes were body-composition measures. Supplements were added to porridge each school day and consumed for 9 mo. Anthropometric and body-composition measures and CANTAB tests were completed upon enrollment and after 4.5 and 9 mo. Group results were compared by using ANCOVA for anthropometric measures and the Kruskal-Wallis test for CANTAB scores. **Results:** Children receiving 8.8 g milk protein/d showed greater increases on percentage correct in Pattern Recognition Memory (mean ± SD: 5.5% ± 16.8%; $P < 0.05$) and Intra/Extradimensional Set Shift completed stages compared with all other food groups (0.6 ± 2.3; $P < 0.05$). No differences were seen in linear growth between the groups. The children receiving either 4.4 or 8.8 g milk protein/d had a higher fat-free body mass index than those who received no milk, with an effect size of 0.34 kg/m^2. **Conclusion:** Among schoolchildren, **the consumption of 8.8 g milk protein/d improved executive cognitive function compared with other supplements and led to the accretion of more lean body mass, but not more linear growth**. This trial was registered at www.clinicaltrials.gov as NCT02757508.

ANNEX 4: ABSTRACTS OF SELECTED PAPERS

Lien DT *et al.* 2009. Impact of milk consumption on performance and health of primary school children in rural Vietnam

This is a follow-up study to an investigation on the prevalence of malnutrition and micronutrient deficiencies among Vietnamese primary schoolchildren. A total of 454 children aged 7 to 8 years attending three primary schools in the Northern delta province of Vietnam were either provided with regular milk, milk fortified with vitamins, minerals and inulin or served as a reference control group. Children were monitored for anthropometrics, (micro)-nutritional status, faecal microbiota composition, school performance, and health indices. Both weight-for-age (WAZ) and height-for-age (HAZ) significantly improved during 6 months of milk intervention; and underweight and stunting dropped by 10% in these groups. During intervention the incidence of anemia decreased and serum ferritin levels increased significantly in all groups. Serum zinc levels increased and consequently the incidence of zinc deficiency improved significantly in all three groups. Serum retinol levels and urine iodine levels remained stable upon intervention with fortified milk whereas in the control group the incidence of iodine deficiency increased. Bifidobacteria composed less than 1% of the total faecal bacteria. After three months of milk intervention total bacteria, bifidobacteria and Bacteroides sp. increased significantly in both milk and inulin fortified milk groups. Children in the milk consuming groups had significantly better short-term memory scores. Parent reported that health related quality of life status significantly improved upon milk intervention. In conclusion, (fortified) milk consumption benefited the children in rural Vietnam including lowering the occurrence of underweight and stunting, improving micronutrients status and better learning indicators as well as improving the quality of life.

A.4.2: MILK/DAIRY CONSUMPTION AND CHILD GROWTH – OBSERVATIONAL STUDIES

Fratkin E *et al.*, 2004. Pastoral sedentarization and its effects on Children's diet, health, and growth among rendille of northern Kenya

Throughout the arid regions of Africa formerly mobile pastoral populations are becoming sedentary. Although pastoral sedentarization is encouraged by international development agencies and national governments as solutions to food insecurity, poor health care, and problems of governance, it has not been demonstrated that abandoning the pastoral way of life, and particularly children's access to milk and other livestock products, is beneficial to the health and well-being of pastoral populations. This paper reports the results of a 3-year study of one pastoral and four settled Rendille communities of northern Kenya based on data from 17 repeated bimonthly surveys of childhood dietary, growth, and morbidity patterns and household level economic strata. Bivariate analysis of 5,535 measurements from 488 children from birth to 9 years revealed that age-specific height and weight measurements for the pastoral community are uniformly heavier and taller than children from the sedentary villages. Multivariate analysis using Generalized Estimating Equations methodology showed that **the amount of milk consumed was always a statistically significant determinant of child weight and height growth, regardless of drought or non-drought times and breastfeeding status**. Other significant determinants of child growth include morbidity and poverty, both associated with sedentary communities. These results indicate that international development assistance should not neglect improvements in livestock production and support of pastoral movements in Africa's arid lands.

Headey D *et al.* 2017. Animal-sourced foods and child stunting.

Stunting affects 160 million pre-school children around the world, and imposes significant costs on a child's health, cognitive development, schooling and economic performance. Stunting in early childhood has been linked to poor dietary diversity, notably low intake of animal-sourced foods (ASFs) rich in high-quality protein and other growth-stimulating nutrients. Surprisingly, however, very little economic research has focused on ASFs and child growth. In this paper we redress this omission through an analysis of 112,553 children aged 6-23 months from 46 countries. We first document distinctive patterns of ASF consumption among children in different regions, particularly highly variable patterns of dairy consumption, low consumption of eggs and meat, and surprisingly frequent consumption of fish in several poor regions of Africa and Asia. We then examine how ASF consumption is associated with child stunting in multivariate models saturated with control variables. **We find strong associations with a generic ASF consumption indicator as well as with fish and dairy consumption**. Finally, we explore why ASF consumption is low but also so variable. We show that non-tradable ASFs (fresh milk, eggs) are a very expensive source of calories in low income countries, and that caloric prices of these foods are strongly associated with children's consumption patterns. A host of other demand-side factors are also important, but the strong influence of prices implies an important role for agricultural policies – in production, marketing and trade – to improve the accessibility and affordability of ASFs in poorer countries.

Hoorweg J *et al.* 2000. Nutrition in agricultural development: intensive dairy farming by rural smallholders

This study concerns the introduction of intensive dairy fanning among rural smallholders in Kilifi District, Kenya. Household surveys were conducted among dairy farmers, dairy customers and a comparison sample from rural locations. Dairy farmers were better off than the rural sample as regards household income, food production, food consumption and nutritional status of young children. These differences resulted from the dairy activities but also from greater involvement in crop cultivation and off-farm employment. Local milk purchases by dairy customers were mostly by wealthier households with wage employment. They had higher incomes and higher food consumption than the rural sample, and the children in these households had better nutritional status. **Further analysis confirms a positive relation between milk consumption and nutritional status of children,**

independent of household income, energy intake and level of education. Other notable findings were the high incomes from off-farm employment of dairy farmers; regular dairy customers are chiefly households with wage employment; milk consumption among the rural population was very low. The results cast doubt on the importance of intensive dairy production as a means of livelihood for resource-poor households and the importance of milk as a means to improve nutritional status of children in low-income households.

Iannotti L & Lesorogol L 2014. Animal milk sustains micronutrient nutrition and child anthropometry among pastoralists in Samburu, Kenya

Milk has been integral to pastoralist nutrition for thousands of years, but as communities move toward settled livelihoods, milk consumption is dropping with only minimal evidence for the health and nutrition implications. This longitudinal study aimed to first test whether increased dependency on agriculture reduced household milk production and consumption, and ultimately, nutrient adequacy among the Samburu pastoralists. Second, we investigated whether household milk availability affected child milk intakes and anthropometry. Socioeconomic and dietary intake data were collected from households (n=200) in 2000, 2005, and 2010, and anthropometric measures and individual child milk intakes in 2012. Nutrient intakes were assessed by the probability of nutrient adequacy method, and generalized least-squared regression modeling with mixed effects was applied to identify predictors of milk consumption. Milk contributed 10% of energy intakes, below maize (52%) and sugar (11%), but over one-half of critical micronutrients, vitamins A, B12, and C. **Livestock holdings and income increased the likelihood of higher milk intakes (overall adj R^2=0.88, P<0.001)**. Undernutrition was widely prevalent among young children: stunting (30.6%); underweight (23.9%); and wasting (8.6%). There was evidence for a previously described Nilotic body type in the youth, who were taller and thinner than the international reference. **Milk consumption at the household level was positively associated with higher body mass index z scores among youth (P<0.001)**. Programming for livestock development may better ensure micronutrient nutrition in Samburu, while deeper investigation into the diet and growth patterns of pastoralists could provide insight into leaner and taller anthropometrics for other populations globally.

Kidoido M, Korir L 2015. Do low-income households in Tanzania derive income and nutrition benefits from dairy innovation and dairy production?

Although the role of Animal-Source Foods (ASFs) in household nutrition is well established, dairy development as a mechanism for reducing poverty and malnutrition is inadequately understood. This study investigated the differences across income strata in contributions of dairy innovations and dairy production to dairy income and nutrition outcomes. Analysis was based on the Tanzania Living Standards Measurement Study-Integrated Surveys on Agriculture (LSMSISA) household panel data of 2008/2009 and 2010/2011. The role of dairy innovations in household income and the importance of dairy income in expenditure on food were estimated using Two-Stage Least-Squares (2SLS). Seemingly

Unrelated Regression (SUR) to analyze the effect of dairy consumption on nutrition outcomes of children below 5 years of age. Although dairy innovations had a positive effect on dairy income, the effect was small among low-income households due to their lack of comparative advantage in accessing and using inputs, output markets and services. Also, their reliance on low productivity dairy animals affected their potential dairy income. **Consumption of dairy products in low-income households was associated with reduced stunting, underweight and wasting**. Wasting in high-income households was only significant among girls. Whereas adoption of dairy innovations and consumption of dairy products have great potential for improving the income and nutrition of low-income households, pro-poor dairy interventions should also be integrated with increasing access to markets and services. Interventions should also incorporate strong gender aware approaches to ensure that the benefits are shared equitably within households.

A.4.3: ('DAIRY') COW/GOATS AND CHILD GROWTH – INTERVENTION TRIALS

Kassa H *et al.*, 2003. Enhancing the role of livestock production in improving nutritional status of farming families: lessons from a dairy goat development project in Eastern Ethiopia

This study was conducted to evaluate the contribution of a dairy goat development project in improving nutritional status of project participants in two districts of Eastern Ethiopia, and to find out better ways of doing so with ongoing included conducting surveys to examine impacts of the dairy goat development project, nutrition education based intervention, and post intervention impact assessment. This paper presents some of the findings of the base line survey conducted on 831 households and that of the formative survey undertaken on 228 project participant and non-participant households. In addition to dietary frequency and anthropometric measurements to assess nutritional and health status of farming families, the surveys covered demographic aspects and livestock holding patterns. Results of the base line survey showed widely varying livestock holding patterns and the generally low nutritional status of people in the two districts. The formative survey that compared project participant and non-participant households revealed that despite project intervention mothers were largely unaware of the causes of and remedies for nutritional deficiency diseases, and health and **nutritional status of women and children did not vary with participation in the project**. It is therefore suggested that if increased milk production and farm income from livestock development projects such as dairy goat farming are to be translated to improved nutritional and health status of women and children, livestock extension messages will have to be complemented with nutrition and health education.

Rawlins R *et al.* 2014. Got milk? The impact of Heifer International's livestock donation programs in Rwanda on nutritional outcomes

International animal donation programs have become an increasingly popular way for people living in developed countries to transfer resources to families living in developing countries. We evaluate the impact of Heifer International's dairy cow and meat goat donation programs in Rwanda. We find that the program substantially increases dairy and meat consumption among Rwandan households who were given a dairy cow or a meat goat, respectively. We also find marginally statistically significant increases in weight-for-height z-scores and weight-for-age z-scores of about 0.4 standard deviations among children aged 0–5 years in households that were recipients of meat goats, and **increases in height-for-age z-scores of about 0.5 standard deviations among children in households that received dairy cows**. Our results suggest that increasing livestock ownership in developing countries may significantly increase consumption of nutrient dense animal-source foods and improve nutrition outcomes.

A.4.4: ('DAIRY') COW OWNERSHIP AND CHILD GROWTH – OBSERVATIONAL STUDIES

Choudhury S & Headey DD 2018. Household dairy production and child growth: Evidence from Bangladesh

Research from richer countries finds that dairy consumption has strong positive associations with linear growth in children, but surprisingly little evidence exists for developing countries where diets are far less diversified. One exception is a recent economics literature using the notion of incomplete markets to estimate the impacts of cattle ownership on children's milk consumption and growth outcomes in Eastern Africa. In addition to external validity concerns, an obvious internal validity concern is that dairy producers may systematically differ from non-dairy households, particularly in terms of latent wealth or nutritional knowledge. We re-examine these concerns by applying a novel double difference model to data from rural Bangladesh, a country with relatively low levels of milk consumption and high rates of stunting. We exploit the fact that a cow's lactation cycles provide an exogenous source of variation in household milk supply, which allows us to distinguish between a control group of households that do not own cows, a treatment group that own cows that have produced milk, and a placebo group of cow-owning households that have not produced milk in the past 12 months. **We find that household dairy production increases height-for-age Z scores by 0.52 standard deviations in the critical 6–23 month growth window, though in the first year of life we find that household dairy supply is associated with a 21.7 point decline in the rate of breastfeeding**. The results therefore suggest that increasing access to dairy products can be extremely beneficial to children's nutrition, but may need to be accompanied by efforts to improve nutritional knowledge and appropriate breastfeeding practices.

Fierstein JL *et al.* 2017. Nonnative Cattle Ownership, Diet, and Child Height-for-Age: Evidence from the 2011 Uganda Demographic and Health Survey

In underresourced settings where domestic animals and children often cohabitate, there is limited evidence about the net impact of domestic animal ownership on child health. We analyzed the 2011 Uganda Demographic and Health Survey to determine whether household ownership of native cattle, goats, sheep, chickens, pigs, and nonnative cattle was associated with child height-for-age z-scores (HAZ), and to assess the influence of diet on this association in rural and urban environments. Using weighted multivariable linear regression, we found that **nonnative cattle ownership was positively associated with HAZ in rural children 0 to < 2 years of age** (+1.32 standard deviations [SD], 95% confidence interval [CI] = 0.2–2.5) and 2 to < 5 years of age (+0.58 SD, 95% CI = 0.003–1.2), and **urban children 2 to < 5 years of age** (+1.08 SD, 95% CI = 0.38–1.8). Sheep ownership was positively associated with HAZ in rural children 2 to < 5 years of age (+0.29 SD, 95% CI = 0.002–0.58) and goat ownership was positively associated with HAZ in rural children 0 to < 2 years of age (+0.27 SD, 95% CI = 0.003–0.55). We observed no other significant associations. **Children who lived in households that owned nonnative cattle consumed dairy more frequently; however, the relationship between child HAZ and nonnative cattle ownership was not mediated by child dairy consumption.** These findings suggest that domestic animal ownership may not be detrimental to child HAZ, and that nonnative cattle ownership is beneficial for child HAZ through pathways other than dairy consumption.

Hoddinott J*et al.* 2015. Cows, Missing Milk Markets, and Nutrition in Rural Ethiopia

In rural economies encumbered by significant market imperfections, farming decisions may partly be motivated by nutritional considerations, in addition to income and risk factors. These imperfections create the potential for farm assets to have direct dietary impacts on nutrition in addition to any indirect effects via income. We test this hypothesis for the dairy sector in rural Ethiopia, a context in which markets are very thin, own-consumption shares are very high, and milk is an important source of animal-based proteins and micronutrients for young children. **We find that cow ownership raises children's milk consumption, increases linear growth, and reduces stunting in children by seven to nine percentage points**. However, we also find that the direct nutritional impacts of household cow ownership are less important where there is good access to local markets, suggesting that market development can substitute for household cow ownership.

Kabunga NS *et al.*, 2017. Does ownership of improved dairy cow breeds improve child nutrition? A pathway analysis for Uganda

The promotion of livestock production is widely believed to support enhanced diet quality and child nutrition, but the empirical evidence for this causal linkage remains narrow and ambiguous. This study examines whether adoption of improved dairy cow breeds is linked to farm-level outcomes that translate into household-level benefits including improved child nutrition outcomes in Uganda. Using nationwide data from Uganda's National Panel Survey, propensity score matching is used to create an unbiased counterfactual, based on observed characteristics, to assess the net impacts of improved dairy cow adoption. All estimates were tested for robustness and sensitivity to variations in observable and unobservable confounders. Results based on the matched samples showed that households adopting improved dairy cows significantly increased milk yield—by over 200% on average. This resulted in higher milk sales and milk intakes, demonstrating the potential of this agricultural technology to both integrate households into modern value chains and increase households' access to animal source foods. Use of improved dairy cows increased household food expenditures by about 16%. **Although under-nutrition was widely prevalent in the study sample and in matched households, the adoption of improved dairy cows was associated with lower child stunting in adopter households**. In scale terms, results also showed that holding larger farms tends to support adoption, but that this also stimulates the household's ability to achieve gains from adoption, which can translate into enhanced nutrition.

Nicholson *et al.* 2003. Dairy Cow Ownership and Child Nutritional Status in Kenya

This study examines the hypothesis that dairy cow ownership improves child nutritional status. Using household data from coastal and highland Kenya, three econometric model formulations are estimated. **Positive impacts on chronic malnutrition are observed for coastal Kenya**. No negative effects on acute or chronic malnutrition are found for either region.

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