



FEED THE FUTURE

The U.S. Government's Global Hunger & Food Security Initiative



Feed the Future Innovation Lab for Livestock Systems

Animal Source Food Consumption and Human Nutrition Annotated Bibliography

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This annotated bibliography is a product of the Health and Human Nutrition Cross-Cutting Theme of the Feed the Future Innovation Lab for Livestock Systems at the University of Florida. The aim is to bring together relevant articles on animal source food consumption and human nutrition that can be of use to researchers and development organizations. This annotated bibliography focuses on the countries, value chains and impact pathways that are most relevant to the research projects funded by the Livestock Systems Innovation Lab, but it is not restricted to those countries.

This is a working document, and it is frequently updated. This current edition was updated in January 2020.

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Cover photo credit: International Federation of Red Cross and Red Crescent Societies, 2015

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Acronyms

AGP	Agricultural Growth Program
ASF	Animal Source Food
CI	Confidence Interval
COP7	Seventh Conference of Parties
CVD	Cardio Vascular Disease
CU5	Children Under 5
DDS	Dietary Diversity Score
DHS	Demographic Health Survey
DNA	Deoxyribonucleic Acid
DRI	Dietary Reference Intake
EE	Enteric Enteropathy
EED	Environmental Enteric Dysfunction
EIA	Enzyme Immunoassay
FAO	Food and Agricultural Organization
FCT	Food Consumption Table
HAZ	Height-for-Age Z-score
HDSS	Health and Demographic Surveillance System
HHH	Head of Household
IGA	Income-Generating Activity
IGF-1	Insulin-like Growth Factor-1
IGFBP-3	Insulin-like Growth Factor-Binding Protein-3
IHD	Ischemic Heart Disease
ILRI	International Livestock Research Institute
IPGRI	International Plant Genetic Resources Institute
IYCF	Infant and Young Child Feeding
LAZ	Length-for-Age Z-score
MetS	Metabolic equivalent of task Score
MDD	Minimum Dietary Diversity
NCD	Non-Communicable Disease
NCRSP	Nutrition Collaborative Research Support Program
OR	Odds Ratio
PCA	Principal Component Analysis
PDCAAS	Protein Digestibility Corrected Amino Acid Score
PER	Protein Efficiency Ratio

SFA	Saturated Fatty Acids
SHEWA-B	Sanitation, Hygiene Education, and Water Supply-Bangladesh
SHINE	Sanitation Hygiene Infant Nutrition Efficacy
SIBO	Small Intestinal Bacterial Overgrowth
SOC	Standards-of-Care
SSA	Sub-Saharan Africa
SPSS	Statistical Package for the Social Sciences
T2DM	Type 2 Diabetes Mellitus
TLU	Tropical Livestock Unit
UHT	Ultra-High Temperature
UNICEF	United Nations Children's Fund
UNFCCC	United Nations Framework Convention on Climate Change
UNHS	Uganda National Household Survey
UNPS	Uganda National Panel Survey
USAID	United States Agency for International Development
VCI	Vulnerability Capacity Index
VHW	Village Health Worker
VIP	Ventilated Improved Pit
WASH	Water, Sanitation, and Hygiene
WAZ	Weight-for-Age Z-score
WHO	World Health Organization
WMS	Welfare Monitoring Survey

Benefits of Animal Source Foods to Human Nutrition

Biological Justification for ASF in Human Diet

Allen, L. H. (2012). Adequacy of family foods for complementary feeding. *The American Journal of Clinical Nutrition*, 95(4), 785-786.

Link: <https://doi.org/10.3945/ajcn.112.035675>

The World Health Organization (WHO) recommends that infants should be breastfed for 18-24 months and should be introduced to semi-solid, complementary foods beginning after 6 months of exclusive breastfeeding. By the age of 12 months, a child should be able and encouraged to consume solid foods that are eaten by the rest of the household—with a heavy influence being placed on animal source foods (ASF) such as meat, poultry, fish, and eggs. In most low-income countries, it is found that the complementary foods chosen do not meet nutrient requirements, specifically micronutrient requirements, which leads to stunting during the first two years of life. Stunting can lead to adverse health consequences for the child which can be carried into adulthood if not remedied. Studies have been conducted on how to best meet the nutrient requirements of children under 5 (CU5), by giving infants and young children different amounts of micronutrient supplements—individual or multiple—to determine the amount needed to meet the micronutrient load requirements. Multiple micronutrient supplementation has been shown to have a small, positive effect on growth and micronutrient status. At the time of the study, few studies had been performed to determine the effects of using family foods to fill the gap of micronutrient deficiency. In order to test this family food theory, Vosselaar and Solomons used a “nutritionally adequate” (criteria not defined) Guatemalan diet (as consumed by ~14% of the 599 adults from poor rural and urban areas in the study population) in calculating the required density of nutrients in complementary foods needed to fill the gap between nutrient intakes from breast milk and daily recommended intakes of children ages 6 to 24 months. Their calculations showed the family food pattern supplied sufficient amounts of B vitamins (thiamine, riboflavin, B-6 and B-12), vitamin C, and protein. However, there was a substantial lack of zinc, calcium and iron, which is commonly seen in young children consuming complementary foods, and a failure to meet critical density levels for vitamins A and B-6 and folate for girls growing at the 15th percentile. The accuracy of the calculations is contingent upon the accuracy of WHO’s recommendations for nutrient intake and values for breast milk composition, which is heavily extrapolated and unable to be thoroughly or directly tested. The composition of the mother’s milk also is dependent upon the mother’s diet and nutritional status. Overall, the analysis is congruent with the previous reports of iron, zinc and calcium gaps in infants and young children eating complementary foods. Additionally, this study showed that the nutrient density of the most nutritionally adequate low-income Guatemalan families’ diets matched or exceeded that needed for complementary feeding. Complementary feeding recommendations encourage the consumption of animal-source foods, fruits, and vegetables which are in short supply in resource-constrained households. It would potentially be unlikely for such foods to be given in higher proportion to the infants or young children rather than the adults.

Allen, L. H. (2017, March). Impact of animal-source food consumption on availability of critical nutrients in breast milk for newborns and infants. *Nurturing development: Improving human nutrition with animal-source foods*. Symposium conducted at the University of Florida, Gainesville, FL.

Link: [Allen](#)

The speaker highlights that pregnant and lactating women need to consume large amounts of micronutrients and provides evidence of higher animal-source foods during pregnancy led to improved outcomes in pregnancy and children. It is noted that animal-source foods provide more energy, fat, protein, and many micronutrients than plant-based foods. While there have been studies on the effect

of maternal micronutrient status on breast milk quality, there are limited studies on the micronutrient status of lactating women and their breast milk quality. The author highlights the two groups of micronutrients important to mother and infant: those which deficiencies can be seen in milk and those which result in depleted micronutrient status of the mother. Much research has focused on B12 but a current study is seeking to establish reference values for each important nutrient over the first nine months of lactation. The author notes that there is little research on the effect of maternal interventions on milk quality and infant health status aside from supplementation.

Barter, J., Diffey, H., Yeung, Y. H., O'Leary, F., Häslar, B., Maulaga, W., and Alders, R. (2018). Use of chicken eggshell to improve dietary calcium intake in rural sub-Saharan Africa. *Maternal and child nutrition*, 14, e12649.

Link: <https://doi.org/10.1111/mcn.12649>

This study uses a mixed-methods approach in the literature to investigate the benefit of adding heat-treated ground eggshells to locally prepared food by increasing dietary calcium intake. Databases from PubMed, Web of Knowledge, and Medline were used to search quantitative research that was published between 1976-2016. The Delphi method which is a two-round modified e-Delphi survey containing qualitative and quantitative question was incorporated to identify opinions on microbial food safety on eggshell consumption. Two rounds of questions were performed on experts on eggshells with six participants in the first round and 5 participants in the second. The survey focused on the level of contamination risk, possible source of contamination, likelihood, and mode of contamination with the types of egg production systems. Five focus group discussions that included 46 people were also used to assess the acceptability of eggshell consumption. Some of the factors within the study include egg microbiology, egg production systems, poultry microbiology, poultry medicine, poultry health, and food safety. Experts indicated that the most likely threat to eggshell consumption was Salmonella, but they all agreed that boiling it for 10 minutes with an additional 20 minutes of cooking grounded eggshells in food would probably eliminate egg-associated pathogens. While there was a general consensus that eggshells were waste there was a willingness or acceptance to consider this approach. One major limitation indicated in the study was the small sample size of experts for the survey, but the small sample size did include internationally renowned experts in their field which makes up for the limitation in size.

Bloem, M. W. (2017, March). From malnutrition to nutrition security. *Nurturing development: Improving human nutrition with animal-source foods*. Symposium conducted at the University of Florida, Gainesville, FL.

Link: [Bloem](#)

The presenter posed a definition for food and nutrition security, and highlighted that food is not the only issue, but also the gamut of factors and pathways which influence nutrition. The speaker presented how natural, physical, human, and social capital assets affect ways of food acquisition, as well as access to food, health care and practices. Additionally, presenting how hygiene conditions can influence food intake, health status, and disease prevalence. The severity of the issues were emphasized through statistics on prevalence of micronutrient malnutrition, calorie deficiency, and stunting. There was emphasis on evidence that shows that maternal health has a large influence on stunting in children, indicating the importance of interventions for this population. Interventions to support optimal nutrition are presented including nutrition-specific and nutrition-sensitive programs; building environments to improve food security, feeding and caregiving resources; and supporting economic wellbeing. The speaker explained the importance animal-source foods on nutrition but potential issues on the supply side such as quality and safety of foods and on the demand side such as lack of knowledge of nutrient needs or affordability. The author identified that market-based solutions need to have local production of products by engaging with both smallholder farmers and the private sector, enforcing a multi-stakeholder approach.

- Dror, D. K., and Allen, L. H. (2011). The importance of milk and other animal-source foods for children in low-income countries. *Food and nutrition bulletin*, 32(3), 227-243.**
Link: <https://doi.org/10.1177/156482651103200307>

The purpose of this literature review was to evaluate the intake importance that milk, and other animal source foods, have in human growth promotion, development, and overall childhood health within low-income countries. This evaluation was conducted using PubMed to search peer-reviewed articles and determine what observational studies and intervention trials had been conducted within the realm of milk and animal source food consumption. Searches in PubMed were conducted using the following search words: “anemia,” “animal source food,” “children,” “egg,” “fish,” “fortified,” “growth,” “intervention,” “meat,” “milk,” “preschool,” “school,” and “supplementation.” Criteria for inclusion in the evaluation required original study to focus on children under 18 and be either, (1) an observational study, or (2) an intervention trial with one or more ASF products—(a) fortified milk, (b) unfortified milk, (c) meat, or (d) other animal source foods. Exclusion criteria included the use of hospitalized children, pregnant women, and populations selected for a prevalence of disease. This paper highlights an older study, where an ASF diet deficiency in The Netherlands showed fewer overall complications, due to better sanitation, which points to WASH as an exacerbation for children with poor nutrition due to a lack in ASF consumption. A study in Kenya showed results that low meat consumption did not show any association to better micronutrient intake, versus no meat consumption, until additional ASF food was supplemented into the diet. The evaluation of observational studies concluded that omnivorous children had significantly higher intakes of calcium, fat protein, riboflavin, and vitamins B₁₂ and C. Additionally, children who relied on macrobiotic diets had significantly lower of these, as well as higher prevalence rates of iron deficiency as infants, delays in gross motor skill development, and adolescent impacts on cognition. The evaluation of intervention trials concluded that only a limited number of randomized, controlled intervention trials had been performed (to-date of publishing) and in order to establish the effects of adding ASF food into childhood diets, more needed to be conducted. The review did yield findings of intervention trials, but most were conducted decades prior, yet all found increased nutrition and growth in children who had ASF added into their diets. The lack of recent intervention trials shows a lack of current-day research with better technology and understanding of ASF consumption and micronutrient intake. The research shows that specifically milk consumption, provides children with macro and micronutrients, fatty acids, and critical growth factors necessary for childhood development. Conclusions state that ASF consumption by children include many benefits (i.e. improved micronutrient status, growth, physical activity levels, and cognitive performance), and that more intervention trials are necessary for better understanding the effects of ASF consumption on childhood nutrition and development.

- Eaton, J. C., Rothpletz-Puglia, P., Dreker, M. R., Iannotti, L., Lutter, C., Kaganda, J., and Rayco-Solon, P. (2019). Effectiveness of provision of animal-source foods for supporting optimal growth and development in children 6 to 59 months of age. *Cochrane Database of Systematic Reviews*, (2).**
Link: <https://doi.org/10.1002/14651858.CD012818.pub2>

This study investigated the effectiveness of ASF compared to other feeding interventions or the lack of one in the improvement of growth and developmental outcomes for children within the ages 6 to 59 months. The methods used within the paper included searching through 22 databases and three trial registers. Studies that were included in the paper were randomized controlled trials and quasi-randomized controlled trials of any duration, in which children within the ages 5 months and 59 months consumed ASF. There were only six studies within the systematic review but it covered about seven countries both from LMIC's and high-income countries. Some of the factors that were incorporated within the study included a comparison of foods prepared in any cooking methods and risk of bias domains which were measured by length-for-age and weight-for-age z scores. Due to the

limited quality of data and evidence, the authors conclude that they were uncertain about the effects of childhood development through the consumption of ASF compared to cereal products or no intervention at all. The authors push for a more adequately powered study that purposefully selects ASF to compare to other variables.

Farshim, P., Walton, G., Chakrabarti, B., Givens, I., Saddy, D., Kitchen, I., ... and Bailey, A. (2016). Maternal weaning modulates emotional behavior and regulates the gut-brain axis. *Scientific Reports*, 6.

Link: <https://dx.doi.org/10.1038/srep21958>

Past studies have shown that brain developments and gut-brain interactions can be influenced in the postnatal period by environmental and nutritional stress stimuli. This study sought to determine the metabolic and gut bacterial effects resulting from weaning. In order to study the connection between behavior and weaning, researchers prevented rats from weaning and tested depressive symptoms. One group of rats was weaned on postnatal day (PND) 21 and the second group was not weaned. Both groups were studied during a forced-swim test on PND 25- non-weaned rats showed a depressive phenotype measured by an increased immobility time. Through fluorescence in situ hybridization, non-weaned rats were also shown to have significantly less *Clostridium histolyticum* bacterial groups (yet exhibiting marked stress-induced increases) than their weaned counterparts. Biochemical phenotypes indicative of depression were found in metabonomic analysis of non-weaned rats' urine. Resistance to stress-induced modulation of oxytocin receptors in amygdala nuclei is typical of a passive stress-coping mechanism and was seen in non-weaned rats. In conclusion, findings showed that delaying weaning leads to changes in gut microbiota and global metabolic profiles, which may contribute to a depressive phenotype. Resultingly, mood disorders at early developmental ages may suggest interplay between mammalian host and resident bacteria.

Frison, E. A., Smith, I. F., Johns, T., Cherfas, J., and Eyzaguirre, P. B. (2006). Agricultural Biodiversity, Nutrition, and Health: Making a Difference to Hunger and Nutrition in the Developing World. *Food and Nutrition Bulletin*, 27(2), 167-179.

Link: <https://doi.org/10.1177%2F156482650602700208>

Micronutrient deficiencies plague the modern world as obesity rates skyrocket, leading to cardiovascular and degenerative diseases. Single-nutrient interventions have shown unsustainable and limited in their success. Now, scientists are turning to food-based approaches, specifically the use of local biodiversity to ensure dietary diversity. The International Plant Genetic Resources Institute (IPGRI) proposed one such strategy that employs agricultural biodiversity as the primary resource people can turn to for health and food security. In this meta-analysis, the authors reviewed information from case studies and food composition and nutritional analysis regarding nutritional properties of traditional foods. Although there have been great strides in chronic hunger reduction, there remains an urgent need for dietary diversification and greater implementation of indigenous and traditional foods. Additionally, the increased availability of high-energy cereal has done little to aid the current 32.7 million malnourished children in sub-Saharan Africa, but has provided an inexpensive, simplified, nutrient poor diet to the growing obesity population. Indigenous foods are being replaced by inexpensive, easy-to-prepare and process cereals devoid of most micronutrients. With urbanization and agricultural reforms, diets have become more simplified, which often means higher in sugar and fat and lower in micronutrient density. For example, in Senegal fats and oils supplied 8% of daily energy requirements in 1963, but in 1998, it supplies 20%. Citing the Maasai pastoralists, the article also discusses the benefits of bio-diversification, highlighting that the pastoralists consume double the recommended amounts of animal fats and a myriad of plant products with powerful antioxidants, resulting in a low incidence of cardiovascular disease in this population. The research suggests intervention in the form of mobilizing traditional food systems and reintroducing indigenous diets through agricultural promotion, nutritional education, and policy development. Several pilot studies of

agricultural biodiversity enhancing nutrition have gone very well, but the studies have not been applied on larger scales. Results of this meta-analysis lead to the conclusion that a holistic food-based approach should combine with nutritional property research and public policy campaigns to reduce micronutrient deficiency and obesity. Based on the multidisciplinary and comparative approach of this study, IPGRI is developing scale-up efforts in different regions of the world that include evaluating the use of local foods, using culturally sensitive methods, and implementing nutrition education to reduce poverty, enhance incomes, and conserve agricultural biodiversity.

Givens, I. (2017, March). The importance of animal-source foods in Western diets. *Nurturing development: Improving human nutrition with animal-source foods*. Symposium conducted at the University of Florida, Gainesville, FL.

Link: [Givens](#)

The author explains in Europe, nutrient deficiencies are becoming common, which can lead to reduced bone mass and potentially osteoporosis. Trends in Europe indicate reduced calcium intake after age 10. There is evidence, the author notes, of higher milk intake in childhood being associated to less of a risk for osteoporotic fractures. The author presents studies have shown women of childbearing age and pregnant woman to have sub-optimal iodine concentration. There has not been found to be a link between dairy consumption and increase in cardiometabolic diseases; studies have found reductions in incidence of stroke with milk consumption, diabetes with yogurt consumption, and cardiovascular disease with cheese consumption. The author concludes that dairy foods and red meat are sources of important nutrients and replacing animal with plant-derived foods may have a negative influence on health. Alternatives such as almond milk do not have the protein density required for good bone development.

Givens, D. I., Livingstone, K. M., Pickering, J. E., Fekete, A. A., Dougkas, A., and Elwood, P. C. (2014). Milk: White elixir or white poison? An examination of the associations between dairy consumption and disease in human subjects.

Link: <https://doi.org/10.2527/af.2014-0009>

The authors of this article sought to determine the effects of milk through a cohort study. Humans are the only mammal species that continues to drink milk throughout life. The amount of milk consumed varies greatly among races. The difference in consumption has been suggested to be attributable to differences in lactose malabsorption, according to a “geographic hypothesis” which states certain communities took up dairying and using milk as food to their selective advantage and slight breeding advantage. The hypothesis is supported by a recent archaeological dig in which DNA from bone samples showed the lactase mutation was absent enabling Neolithic subjects to consume unlimited amounts of dairy. Milk consumption declined with the rise of urban growth. Pasteurization, however, provided a safe way to transport and consume milk in the cities, which increased its presence once more. Currently, vast disagreement and public confusion exist on the dangers and benefits of milk. To determine effect of milk, the authors examined correlations between health and disease and milk consumption through prospective cohort and case-control studies. Outcomes include the following: milk consumption is positively correlated to growth in elementary-aged children. Milk contains Ca that is essential for bone growth and strength. For adults, body weight and central obesity has been negatively correlated with milk consumption (OR=0.56). While dairy products provide saturated fatty acids, which can raise total blood cholesterol and LDL levels, current research fails to show a hypercholesterolaemic effect of dairy products and even that dairy contributes to HDL levels. Firm conclusions cannot be drawn regarding whole milk and dairy products’ effects on cardiovascular disease. Milk and total dairy products have been associated with a reduction in colorectal cancer risk. Health benefits of reduced fat milks are still inconclusive. In summary, the authors believe that public health nutrition policy in regard to dairy consumption should not be solely determined by believed

negative effects of dietary fat but should be evidence-based. Finally, milk is not a “white elixir,” nor does the evidence support it being a “white poison.”

Ghosh, S. (2017, March). Stunting and malnutrition in the developing world. *Nurturing development: Improving human nutrition with animal-source foods*. Symposium conducted at the University of Florida, Gainesville, FL.

Link: [Gosh](#)

The speaker illustrates the importance of micronutrient deficiencies and the issues with stunting and undernutrition in South Asia and Sub-Saharan Africa, which are of most concern as these countries have high numbers of stunting, wasting, and underweight children. The speaker mentions the large number of cases of micronutrient deficiencies these countries face. Many of the countries have multiple public health hazards. The global nutrition targets for 2025 are explained. The speaker highlights that stunting is cyclical, multi-faceted, and complex and explains the factors which may influence malnutrition, when they can occur, and at which ecological level they occur.

Havelaar, A. (2017, March). Livestock and the global burden of zoonotic and foodborne diseases. *Nurturing development: Improving human nutrition with animal-source foods*. Symposium conducted at the University of Florida, Gainesville, FL.

Link: [Havelaar](#)

The speaker provides evidence of the risk of animal-source foods as animals are common reservoirs for emerging infectious diseases. Africa and Southeast Asia face a higher DALY burden of livestock-related zoonoses. The pathways between livestock disease and human nutrition are explained by the speaker, including how poverty and non-food factors influence this cycle. The speaker notes the bacteria which account for the largest amount of DALYs by food group. The author highlights children under five suffer disproportionately from foodborne illnesses. The risks in addition to the benefits of animal ownership have been found in studies which concluded that benefits may be negated or reduced by exposure to animal feces.

Hawkes, C., Demaio, A. R., and Branca, F. (2017). Double-duty actions for ending malnutrition within a decade. *The Lancet Global Health*.

Link: [https://doi.org/10.1016/S2214-109X\(17\)30204-8](https://doi.org/10.1016/S2214-109X(17)30204-8)

This opinion piece stresses the urgency of addressing the double burden of childhood undernutrition that is increasing worldwide. The double burden shows that stunted children are more likely to be affected by adult onset health issues. In 2016, of the 129 countries surveyed, 59 were found to have significant levels of childhood stunting, or anemic and overweight adults. Stunted children were found to be more likely to become overweight/obese as an adult, as well as be more susceptible to non-communicable diseases (NCDs). The authors stress how the double burden of malnutrition is presenting new challenges to the healthcare world, and how interventions, programs, and policies to mitigate childhood stunting, should also aim to prevent adult burden of disease and DALYs worldwide. Authors place emphasis on the needs for micronutrient programs to help best combat both sides of this double burden in nutrition.

Herrador, Z., Perez-Formigo, J., Sordo, L., Gadisa, E., Moreno, J., Benito, A., ... Custodio, E. (2015). Low dietary diversity and intake of animal source foods among school aged children in Libo KemKem and Fogera districts, Ethiopia. *PLOS ONE*, 10(7), 1-19.

Link: <https://doi.org/10.1371/journal.pone.0133435>

This study explores the food consumption and dietary diversity patterns among school-aged children in Northwest Ethiopia. It was conducted in the Libo Kemkem and Fogera *woredas* of Ethiopia. The

study sample was selected through the implementation of a multistage cluster survey, with primary sampling units being randomly selected from sub-districts (*kebeles*), secondary sampling units being randomly selected from villages (*gotts*), and third sampling units being randomly selected from households within each randomly selected village. A total of 889 children between 4 and 15 years of age were recruited for the study. There were three questionnaires (individual, household and community) that collected information on assets and services at the community level; household information on socio-demographic characteristics, house construction materials, and assets; and information at the individual level on behavioral and biological characteristics, including a 24-hour dietary recall. Data were analyzed using Statistical Package for the Social Sciences (SPSS). The Dietary Diversity Score (DDS) was calculated by summing the number of unique food groups and followed the Food and Agriculture Organization's (FAO) guidelines. Eighty percent (80%) of the sample lived in rural areas with 78.9% having a low tertile DDS—defined as the consumption of less than or equal to 3 diverse food groups). The prevalence of low DDS was significantly higher in rural areas than urban. The percentage of children consuming ASFs was significantly higher in the urban settings compared to the rural settings (64% vs. 18.1%, respectively, $p < 0.001$), despite the fact that 96.3 of families in rural sites owned animals vs. 36.5% of families in urban sites. This echoes the importance of livestock as an asset that may be preferably sold in markets instead of consumed by the family. Intake of ASFs was also lower among rural girls than rural boys. In the rural settings, children had a lower DDS when the head of the household (HHH) was male and older than 40 years old when compared to instances when the HHH was female and younger than 40 years old (OR: 1.91; 95% CI 1.00-3.65; and OR: 1.56; 95% CI 1.02-2.38, respectively). These results are in line with other research findings which suggest that female HHHs allocate resources in a more efficient way that support better health and nutrition outcomes for the household. In the rural sites, a lower DDS was found during the post-harvest season, yet no difference was observed for ASF intake during the time of lean season. Overall, this study found that school-aged children in Libo Kemkem and Fogera districts lacked dietary diversity and had low ASF consumption, particularly among rural girls.

Hoffman, J.R., and Falvo, M.J. (2004). Review Article: Protein-Which is Best? *Journal of Sport Science and Medicine*, 3(2004), 118-130.

Link: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC24482589/>

This paper seeks to identify which protein is best for both the general and athletic populations. There are several methods to determine protein quality, including protein efficiency ratio (PER), biological value, net protein utilization, and protein digestibility corrected amino acid score (PDCAAS). Protein from animal sources provides the highest quality rating of food sources and includes whey, casein, and bovine colostrum. Protein from vegetable sources is considered incomplete because they generally lack one or two essential amino acids. Plant-based sources of protein include legumes, nuts, and soy. Limited research is available on various protein sources and their effects on human performance. One study comparing casein and whey protein supplementation on body composition and strength indicators found, after 12 weeks of supplementation on overweight police officers, significantly greater strength and lean tissue accrue in subjects given casein compared to whey. Studies exploring the benefits of bovine colostrum vs. casein in non-elite athletes have been inconclusive. Another study comparing casein and whey protein supplementation found that whey protein triggers rapid synthesis of protein but a large part of it is used as fuel (oxidized), while casein may result in a greater protein accumulation over a longer period of time. One study comparing colostrum, whey, and casein supplementation found no significant differences in lean body mass, strength, or power performance following 12 weeks of supplementation in subjects training for recreational purposes. There are some concerns regarding high protein diets, including metabolic disease risk, cardiovascular disease risk, impaired renal function, and increased calcium excretion by bones. This paper concluded that a combination of proteins from different sources is likely best for optimal performance.

Hulett, J. L., Weiss, R. E., Bwibo, N. O., Galal, O. M., Drorbaugh, N., and Neumann, C. G. (2014). Animal source foods have a positive impact on the primary school test scores of Kenyan schoolchildren in a cluster-randomised, controlled feeding intervention trial. *British Journal of Nutrition*, 111(05), 875-886.

Link: <https://doi.org/10.1017/S0007114513003310>

This cluster-randomized, intervention trial introduced animal source foods into the diets of school children in Kenya, and analyzed the test score differences between the different feeding groups of children. The study was conducted in the Eastern Province of Kenya—Embu District. This area of Kenya relies on the subsistence farming provided by local farms. A total of 12 of the 18 primary schools in Embu were chosen, and randomly appointed to either a control group or one of three intervention groups receiving isoenergetic feedings. The three isoenergetic feeding group consisted of the three following options—a local plant-based stew with meat, a local plant-based stew with whole milk, or the local plant-based stew with added oil. The feeding intervention was administered in the form of a mid-morning snack. The control group received no feeding intervention. A long-term baseline was established, which was followed by an intervening feeding time of 5 consecutive school terms, in a 2-year timeframe (1999-2001). The longitudinal analysis was controlled for the children's school attendance, energy intake socio-economic status, age, sex, and literacy of mother. For analysis purposes, only 360 children were utilized in the study. The test scores were compared utilizing ANOVA tests with a confidence interval of 95% for analysis. Results showed that the children whose diets were supplemented with meat in the plant-based stew had significant improvement in test scores, compared to all other intervention and control groups.

Iannotti, L. L., Lutter, C. K., Stewart, C. P., Riofrío, C. A. G., Malo, C., Reinhart, G., ... and Waters, W. F. (2017). Eggs in early complementary feeding and child growth: a randomized controlled trial. *Pediatrics*, e20163459.

Link: <https://doi.org/10.1542/peds.2016-3459>

The consumption of eggs has long been debated as one of the best sources of nutrition, yet over the course of human history, many societies have stigmatized the consumption of eggs. The authors of this study hypothesized that if eggs were introduced into the diets of young children during complementary feeding that it would improve a child's nutritional status. In order to test the hypothesis, the authors conducted a randomized control study in the Cotopaxi Province of Ecuador from March-December of 2015. The study population consisted of children ages 6-9 months of age who were randomly assigned to either the treatment group, or the control group. The treatment group consisted of 83 children who received one egg per day for 6 months. The control group consisted of 80 children who received no intervention. Households in both groups were monitored closely during the 6-month study period, with weekly visits taking place to distribute eggs to the treatment group, and to monitor morbidity symptoms in both groups—no allergic reactions to the eggs were ever reported in this study population. Data were analyzed using a linear regression model to compare length-for-age z-scores (LAZ) and WAZ scores, as well as a log-binomial model to examine the nutritional outcomes between each group. Linear regression findings (95% CI) showed that the treatment group receiving one egg per day for 6 months showed an increase in LAZ by 0.63 and an increase in WAZ by 0.61. Log-binomial findings showed a reduction in the prevalence of stunting by 47%, and underweight by 74% in the treatment group when compared to the control group of the study. Due to the findings, authors conclude that when eggs are introduced into a child's diet during complementary feeding it significantly decreases stunting and increases nutritional status.

Iannotti, L., and Lesorogol, C. (2014). Animal milk sustains micronutrient nutrition and child anthropometry among pastoralists in Samburu, Kenya. *American journal of physical anthropology*, 155(1), 66-76.

Link: <https://doi.org/10.1002/ajpa.22547>

This longitudinal survey monitored the dependency on agriculture and its effect on household milk production and consumption, as well as, household milk availability and how a child's milk intake and anthropometrics were affected. The study was carried out in the Samburu County of Kenya, with 200 households being selected in the communities of Siambu and Mbaringon. All households were surveyed during 2000, 2005, and 2010—the households were asked for a 24-hour recall on the household food and milk production, and dietary intake. In 2012, the survey added the anthropometric measurements of children aged 0-18 years old, as well as individual milk intake of each child. Of the original 200 households in the study, 55 from Mbaringon were included in the child data collection. The time of day and manner of milk consumption were asked (i.e. in tea, with porridge or other cereals). The anthropometric measurements consisted of measuring the height/length and weight on all children under the age of 18 years of age. Results found that there were positive relationships with both, household milk intake and BMI z-scores among children, as well as cattle ownership by household and weight-for age z-scores (WAZ). Additional results showed that the female-headed households were negatively associated with height-for-age z-scores (HAZ); however, this was concluded to be due to income. The discussion notes that data collection on the Samburu diet and milk consumption are outdated and should be re-examined due to changes in climate and land use.

Kaimila, Y., Divala, O., Agapova, S. E., Stephenson, K. B., Thakwalakwa, C., Trehan, I., ... and Maleta, K. M. (2019). Consumption of animal-source protein is associated with improved height-for-age z scores in rural Malawian children aged 12–36 months. *Nutrients*, 11(2), 480.

Link: <https://doi.org/10.3390/nu11020480>

Due to the primarily plant-based diets in LMIC's, young children do not receive the essential protein and micronutrients that are required. This study assesses the relationship between the type of food and the quality of protein which leads to stunting among children (ages 6-36 months old) living in Masenjere and Limera in rural Malawi. The study is a secondary analysis of two randomized control trials that investigated the effects of bean and cowpea flour on stunting in children. Food intakes of 335 children were compared between regions using chi-square and student's t-test. Some of the factors within the study included measuring minimum dietary diversity, protein quality assessment, and environmental enteric dysfunction. The study indicates that protein consumption is higher, and stunting is lower among the children living in Limera who have diets that incorporate a higher amount of ASF while stunting is greater among Masenjere, who's children consume less ASF. Because both villages were located near rivers or lakes, the incorporation of fish within diets to provide micronutrition was feasible. Although children from Masenjere scored higher for the minimum required dietary diversity, it was not associated with growth, but other studies have shown that dietary diversity does provide improved anthropometric outcomes for children. The study concludes by pushing programs that consist of incorporating more fish into children's diets. It is not only a cheap source of protein but could provide essential micronutrients as well. Some of the limitations within the study included the lack of necessary dietary recalls conducted per person to reduce uncertainty, as well as the bias associated with the dietary, recalls due to the parents incorporating different foods when recalls were conducted.

Keunen, K., Elburg, R. M., Bel, F. V., and Benders, M. J. (2014). Impact of nutrition on brain development and its neuroprotective implications following preterm birth. *Pediatric Research*, 77(1-2), 148-155.

Link: <https://doi.org/10.1038/pr.2014.171>

This review aims to summarize the influence of early postnatal nutrition on brain development following extremely and very preterm birth. Prenatal exposure to undernutrition has been associated with cognitive impairments, learning disabilities, and schizophrenia, but these effects are dependent on the time and duration of the undernourishment. The authors' review of research highlights that only a

few studies have evaluated the influence of nutrition on brain volumes and neurodevelopment. One study of pre-term infants with white matter disease, compared to full-term infants with neonatal encephalopathy highlighted the significant head growth, weight gain, and increased axonal diameters in the corticospinal tracts as a result of a high energy and protein diet in the first year after birth. This review also explores the nutritional supplements that may serve as neuroprotective agents. The authors examine the effects of glutamine supplementation in that glutamine may offer direct benefits in white matter development and may reduce systemic inflammation. The authors also discussed probiotics as another nutritional supplement which can favorably alter the immune response of a preterm brain resulting in less inflammation, and thus can diminish white matter injury. Ultimately, nutritional therapies may offer benefits to the developing brain and reduce the incidence of postnatal infections as well as decrease inflammation, subsequently diminishing white matter injury in pre-term infants.

Lovegrove, J., and Givens, D. (2016). Dairy food products: Good or bad for cardiometabolic disease? *Nutrition Research Reviews*, 29(2), 249-267.
Link: <https://doi.org/10.1017/S0954422416000160>

Type 2 diabetes mellitus (T2DM) prevalence has been sharply increasing and is known to be a key risk for Cardiovascular Disease (CVD). Since CVD is the leading cause of death globally, dietary risk reduction has been shown recent attention. One method is to reduce saturated fatty acid (SFA) intake, which has meant reducing milk and dairy products since they are the largest contributors of saturated fats in the UK. Evidence from prospective cohort studies, however, does not confirm the association between CVD, T2DM and metabolic syndrome risk and dairy product consumption. Studies conducted on women's butter intake and Ischemic Heart Disease (IHD) mortality showed a positive correlation (per 10 g/d; rate ratio mortality 1.04; 95% CI 1.01, 1.06) yet found no correlation between butter consumption and stroke in men. Evidence for cheese is also limited. Accounting for 90% of all diabetes cases is T2DM, which is continuing to increase at alarming rates. Milk and dairy products have been shown in many recent studies to decrease the risk of T2DM and the metabolic equivalent of task score (MetS), possibly due to the composition of dairy which has protein, Ca, vitamin D, dairy fat and trans-palmitoleic acid. Reviewed data leads to the conclusion that dairy consumption is associated with reduced blood pressure and not associated with an increase in body weight. Due to several prospective cohort studies showing a negative correlation between dairy product consumption and CVD risk, the authors concluded that decreasing dairy foods to lower SFA intake and consequently reduce CVD risk is likely to have limited positive effects, but more likely potential negative effects on the human body.

Lutter, C. K., Iannotti, L. L., and Stewart, C. P. (2018). The potential of a simple egg to improve maternal and child nutrition. *Maternal and child nutrition*, 14, e12678.
Link: <https://doi.org/10.1111/mcn.12678>

This study builds on a previous review to address the benefits of egg consumption to maternal and child nutritional requirements, specifically on its effects on breast-milk consumption, brain development, and finally how cultural beliefs and egg taboos might affect the consumption of eggs. Some of the factors included in the review are the composition of breast milk, Lunlun Project, brain developmental function, breast milk composition, and women in reproductive age. When comparing eggs to other single nutrient supplements, micronutrients like choline and docosahexaenoic acid are found to be more easily absorbed. Children in the rest of the world consume about three times more eggs than children in Africa and for women that are in reproductive age, the consumption of eggs is strongly related to socio-economic wealth. Although the study does indicate cultural stigma surrounding egg consumption during pregnancy, lactation, and early childhood, economic barriers were still more important to overcome. It is suggested that well-informed social marketing, as well as a behavioral change strategy, have led to extensive increases in egg consumption among young children.

McLean, E. D., Allen, L. H., Neumann, C. G., Peerson, J. M., Siekmann, J. H., Murphy, S. P., ... and Demment, M. W. (2007). Low Plasma Vitamin B-12 in Kenyan School Children Is Highly Prevalent and Improved by Supplemental Animal Source Foods. *The Journal of Nutrition*, 137(3), 676-682.

Link: <https://doi.org/10.1093/jn/137.3.676>

This study examined whether plasma vitamin B-12 concentrations were associated with dietary sources of the vitamin at baseline and whether increasing the intake of milk or meat would improve a child's vitamin B-12 status after one or two years of feeding. It was investigated as a sub-study within the framework of the Global Livestock Collaborative Research Support Program. The study was conducted in Kyeni South Division of Embu District in Kenya because it was an area cited with low intake of ASF and vitamin B-12. The study included 503 schoolchildren, ranging in age from 5 to 14, who were recruited from 12 primary schools and randomly assigned to 1 of 4 experimental groups, which included a control group and 3 groups which received a variance of a tradition vegetable stew (*githeri*) made of maize, beans, and seasonally available vegetables.

1. Control: no food provided
2. *Githeri* snack
3. *Githeri* and milk snack
4. *Githeri* and meat snack

The children were fed while in school 5 days per week for 9 months out of the year for 2 years. Dietary information of the children was collected through questionnaires directed to the mothers and general medical examinations were done of the children at the baseline, at 1 year, and at 2 years. The results of the study showed that the children were moderately stunted and that the stunting differed by intervention group. Wasting, however, was less prevalent in the children. The intervention indicated that supplemental ASF (meat or milk) in a child's diet resulted in improved plasma vitamin B-12 concentration after 1 and 2 years. Because these interventions almost completely eliminated low plasma B-12 concentrations, it is deduced that these children's low levels of plasma vitamin B-12 is a result of inadequate ASF intake, rather than the result of malabsorption of the vitamin caused by *Helicobacter*-induced gastric atrophy.

Murphy, S. P., and Allen, L. H. (2003). Nutritional importance of animal source foods. *The Journal of nutrition*, 133(11), 3932S-3935S.

Link: <https://doi.org/10.1093/jn/133.11.3932S>

The purpose of the article is to address the advantages of a combination diet that includes adding animal source foods to a plant-based diet. The paper addresses results found in the 1980s, conducted by the Nutrition Collaborative Research Support Program (NCRSP), which found malnourishment in the primarily vegetarian diets of school children in Egypt, Kenya, and Mexico. The children's diets were found to be low in 6 micronutrients—calcium, iron, riboflavin, vitamins A and B-12, and zinc. Many health issues arise from these micronutrient deficiencies, which include anemia, cognitive impairment, rickets, stunting, neuromuscular deficiencies, blindness, and sometimes death. NCRSP findings also indicated that a higher quality diet indicated more intake of ASF. In all three countries, the intake of animal source energy and animal source protein had a positive correlation with intakes of Vitamins A and B-12, as well as riboflavin. Additionally, the same findings showed that intake of just animal source protein to be the strong predictor of calcium intake in the countries of Egypt and Kenya; however, this was not the case for Mexico due to calcium intake provided by the consumption of tortillas prepared with lime. The findings in Kenya showed that within a population of 49 toddlers, when nutrient intakes were compared—6 days of no ASF consumption to 6 days of some ASF consumption—the micronutrient intakes of vitamin B-12, calcium, fat, phosphorus, protein, and riboflavin were found significantly higher on days when some ASF was consumed. This means that

for diets that rely solely on plant-based sources of foods, more variety is needed to meet micronutrient requirements; however, that may not be possible due to availability and access. The paper discusses findings from a Dutch study that showed infants of strictly vegan (macrobiotic) diets had lower nutritional status and were more susceptible to getting rickets and having deficiencies in iron and Vitamin B-12. Research in Nepal showed that children who had relatively high fish, or meat, intake between the ages of 13 to 24 months of age, were less likely to develop xerophthalmia as a child. The panel for Dietary Reference Intakes (DRI) assumed an 8% difference in iron absorption between vegetarian diets (10% iron absorption), and a mixed diet (18% iron absorption). This led to a recommendation that vegetarians need 80% more iron in their diet to make up the difference in absorption. The paper also discusses the Hullett, et. al. study where milk and beef snacks were provided to school children in Kenya, with positive findings in an increase to the micronutrient intake of the children receiving the milk and beef snacks—these snacks only accounted for 20% of the recommended energy requirement for the children. The most important takeaway from this paper and findings within, is that ASF can fill more micronutrient gaps than plant source foods, and at lower intake volumes.

Neumann, C., Harris, D. M., and Rogers, L. M. (2002). Contribution of animal source foods in improving diet quality and function in children in the developing world. *Nutrition Research*, 22(1-2), 193-220.

Link: [https://doi.org/10.1016/S0271-5317\(01\)00374-8](https://doi.org/10.1016/S0271-5317(01)00374-8)

This literature review discusses the benefits of ASF and their main micronutrients that improve the quality of the human diet as well as the adverse consequences of micronutrient deficiencies in the diet. The authors highlight that the main advantage of ASF is their high content of micronutrients because there is a high level of absorption and utilization by the body because of the heme protein that is only found in meat, fish, and poultry. Leafy plants cannot provide this same advantage because although they are high in nutrients, they are poorly absorbed by the body. The review then examines different micronutrients in more depth, discussing iron, zinc, and vitamin B-12. When discussing iron, the paper differentiates mild and severe iron deficiency, emphasizing that mild deficiency involves depleted iron stores and no anemia while severe deficiency is characterized by a low hemoglobin concentration. Zinc, involved in gene expression, cell division, and DNA synthesis, plays a major role in a variety of biochemical enzymatic processes relevant to maternal and child survival. Vitamin B-12 is ultimately derived from bacterial synthesis making the risk of deficiency high for vegetarians, especially those who eat no foods of animal origin. Infants who are born to mothers with low vitamin B-12 concentrations are left with poor stores of the vitamin making them particularly prone to deficiency. The review also examined the benefits of animal source foods, citing findings from the Human Nutrition Collaborative Research Support Program that showed maternal intake of ASF to be positively associated with infant growth *in utero*. In turn, there is a positive association of intake of ASF and linear growth in children. This paper also highlights how cognitive function is related to ASF consumption referring to a study in which Kenyan children who consumed animal source foods had greater cognitive performance and showed more leadership behavior. Micronutrient deficiencies that result from a lack of ASF are related to cognitive function such as in the fact that iron deficiency has a strong association with reduced mental and motor developmental indicators, even in mild cases of iron deficiency anemia. The authors acknowledge some of the challenges of including ASF in the diet in order to prevent deficiencies, including that many view animal production as an inefficient mean of food production because animals are seen as direct competitors with humans for foods such as corn and grains. However, animals increase the efficiency of the farming system and contribute to the farm economy in a number of ways. Ultimately, the authors identify that animal source foods have a positive impact on the micronutrient enhancement of the diets of women and children. The review suggests that investing in the diets of women and children would maximize growth, cognitive development, and school performance which ultimately results in greater social and economic development of the community and nation as a whole.

- Payling, L. M., Juniper, D. T., Drake, C., Rymer, C., and Givens, I. D. (2015). Effect of milk type and processing on iodine concentration of organic and conventional winter milk at retail: Implications for nutrition. *Food Chemistry- Elsevier*, 178, 327-330.**
Link: <https://doi.org/10.1016/j.foodchem.2015.01.091>

Approximately 44% of children and adults in Europe are mildly iodine deficient. Many countries and regions, such as the United Kingdom (UK) have not iodized their salt—a wide-spread intervention used in the US to reverse and prevent iodine deficiencies. The US Institute of Medicine proposes an increase of 47% and 93% of iodine during pregnancy and lactation respectively. WHO recommends an increase of 67% for women who are either pregnant or lactating. Current urinary iodine concentration studies have shown that about 51% of schoolgirls in the UK are mildly iodine deficient. Low maternal iodine status during pregnancy has been linked to poorer verbal IQ, reading comprehension and reading accuracy in the children. Milk and dairy foods currently provide the largest dietary source of iodine to people in the UK (~40%) and those dairy foods are largely consumed in the form of semi-skimmed milk (~43%). Studies of the Food Standards Agency show that UK milk iodine levels are highly variable; on average, summer milk's iodine level is consistently 50% lower than winter milk's iodine level. Additionally, summer milk from organic dairies had about 40% lower iodine concentrations than from conventional systems. UK studies were conducted to compare iodine content of 1. Organic and conventional winter milk; 2. Whole, semi-skimmed and skimmed milk; and 3. Pasteurized and ultra-high temperature (UHT) treated milk. The various types of milk were purchased three times at a local grocery store in the first three weeks February. All were stored at -20 degrees Celsius overnight, defrosted, mixed, vortexed, and then analyzed. Iodine concentration was measured by alkali extraction and by inductively coupled plasma mass spectrometry. Results showed milk's fat class had no effect on iodine concentration, but production system effected it greatly (organic milk was 32.2% lower than conventional). Findings showed that UHT milk was 30% lower in iodine than pasteurized milk. Thus, the authors concluded that organic or UHT milk will increase the risk of sub-optimal iodine levels.

- Pimpin, L., Kranz, S., Liu, E., Shulkin, M., Karageorgou, D., Miller, V., ... and Mozaffarian, D. (2019). Effects of animal protein supplementation of mothers, preterm infants, and term infants on growth outcomes in childhood: a systematic review and meta-analysis of randomized trials. *The American Journal of Clinical Nutrition*.**
Link: <https://doi.org/10.1093/ajcn/nqy348>

In this systematic review and meta-analysis of randomized trials, animal protein supplementation and birth and growth outcomes were investigated in mothers, preterm infants, and term infants/children. The study looked at 6808 articles through PubMed, EMBASE, Cochrane library, Web of Science, Cumulative Index of Nursing and Allied Health Literature, and Latin American and Caribbean Health Science. The articles were based on trails that implemented supplements, foods based on animal protein, and a mix of both animal and plant protein. Some of the factors included in the study are potential sources of heterogeneity, types, and level of protein, and forms of intervention. Protein from animals did not provide great benefits to mothers and preterm infants and only provided growth in weight while food-based supplementation during childhood not only reduced the risk of stunting but also increase WAZ. The study notes that the incorporation of ASF without formula was the only one to increase height of age. The best outcomes that were identified within the trials were when both the mother and the child were supplemented which resulted in an average of a 100-gram increase in weight and a 0.1-centimeter increase in height. The study press for further research indicating caution on the interpretation of their results due to the variation in the studied population as well as the level of protein, varying foods used, and the types of protein incorporated within the studies.

- Schonfeldt, H. C., Pretorius, B., and Hall, N. (2013). The impact of animal source food products on human nutrition and health. *South African Journal of Animal Science*, 43(3), 394-412.**

Link: <http://dx.doi.org/10.4314/sajas.v43i3.11>

This article reviews the most-recent findings of the time (pre-2013) and discusses the role ASF consumption has in a nutritious South African diet, as well as addresses common health-related concerns to ASF consumption. The authors discuss the dichotomized view of ASF consumption, noting that ASF can be beneficial or harmful, to humans. In order to maintain a healthy diet, the micronutrient intake provided by ASF is necessary; however, that some animal source foods are high in saturated fats and could exacerbate the growing obesity concerns. South Africa, itself, is very dichotomized in the realm of nutritional imbalance, posing a double-burden. Whilst 5 of the top 10 reasons for death include health issues that may be mitigated with a healthy diet—diabetes, excess body weight, high blood pressure, high cholesterol, and physical inactivity. This is a stark comparison to the fact that the 12th greatest risk factors for death in South Africa are childhood and maternal underweight, with the 14th and 16th leading causes being vitamin A deficiency and iron deficiency anemia, respectively. With 8 of the top 16 leading causes of death being diet-related, the authors argue for better educational implementation on the benefits and risks of a healthy, ASF-inclusionary diet. In conclusion, the authors argue for adherence to the South African Food-Based Dietary Guidelines, which recommends (up to) 560 g of lean, red meat per week. The authors noted many times that the availability of such food to the under-nourished is a distinct barrier to this consumption and call for a more programmatic response to utilizing the benefits of ASF-based diets to combat constant undernutrition.

Semba, R. D., Shardell, M., Ashour, F. A. S., Moaddel, R., Trehan, I., Maleta, K. M., ... and Manary, M. J. (2016). Child stunting is associated with low circulating essential amino acids. *EBioMedicine*, 6, 246-252.

Link: <https://doi.org/10.1016/j.ebiom.2016.02.030>

The purpose of this study was to examine the relationship between a lack of essential amino acids and child stunting. Within the past few decades, programs to improve child malnutrition in developing countries have shifted their focus from protein to micronutrient deficiencies; however, the authors believe protein may be more important in preventing child stunting due to major metabolic and growth pathways (mTORC1 and GCN2) in children relying on adequate intake of essential amino acids. mTORC1 and GCN2 depend on the availability of amino acids to synthesize proteins and lipids and to stimulate cell growth. To analyze this potential association, the authors conducted a cross-sectional study on 313 children from six different villages in rural Malawi, all within the age range of 12 to 59 months. They hypothesized that stunted children would present with lower concentrations of essential amino acids and other key metabolites in their blood samples as compared to non-stunted children. 139 different metabolites from blood serum were extracted and measured via mass spectrometry, including amino acids, biogenic amines, amino acid metabolites, sphingolipids, acylcarnitines, and glycerophospholipids. Each metabolite was chosen on the basis of importance for the growth and development of children. A child was defined as stunted if they had a height-for-age Z score (HAZ) more than -2 standard deviations below the standard WHO growth curve. The study found stunted children to have lower circulating concentrations of all nine essential amino acids, confirming their hypothesis. 16 amino acids, including eight of nine essential amino acids, were significantly correlated with HAZ. The major amino acid sensed by the mTORC1 pathway, leucine, was found to be the amino acid most strongly associated with child growth. Due to low serum levels of sphingomyelins, the results also suggest choline-poor diets, most likely lacking in animal-based foods. Without choline, synthesis of sphingomyelins and phosphatidylcholines is not possible, inhibiting bone growth, cell growth and differentiation, and more fundamental processes during critical periods of development. Although longitudinal studies and controlled trials are needed to confirm the direct impact of amino acid intake on the major growth pathways discussed, the results from this study suggest increasing the protein and choline in diets of children living in developing countries could lead to decreased prevalence of stunting.

Shapiro, M. J., Downs, S. M., Swartz, H. J., Parker, M., Quelhas, D., Kreis, K., ... and Fanzo, J. (2019). A Systematic Review Investigating the Relation Between Animal-Source Food Consumption and Stunting in Children Aged 6–60 Months in Low and Middle-Income Countries. *Advances in Nutrition*, 10(5), 827-847.

Link: <https://doi.org/10.1093/advances/nmz018>

In this systematic review, the authors analyzed the correlation between stunting in children who were 6 months – 60 months old and ASF in LMIC's as well as the relationship between the consumption of ASF and other growth and developmental indicators. Databases such as CINAHL, Embase, Global Index Medicus, PubMed, and Web of Science were used to collect randomized control trials and cross-sectional studies to identify the association between consuming ASF and reducing stunting in children. The collected data included 14,783 records, 116 full-text articles. Some of the factors included within the study are the risk of bias, iron status among individuals, the role of breastfeeding, infant formulas, and variables that measured growth. The review showed no significant relationship between stunting and ASF and only 2 studies out of the 21 studies concluded in a relation between both factors. The authors do note that this was possibly due to the inconsistencies in study designs in the various studies within their systematic review. The authors emphasize that future studies that analyze the correlation between stunting and the consumption of ASF will need to identify and show the consistency in how people define and quantify the exposures and outcomes to allow for a better comparison of the two factors across varying studies.

Stewart, C. P., Caswell, B., Iannotti, L., Lutter, C., Arnold, C. D., Chipatala, R., ... and Maleta, K. (2019). The effect of eggs on early child growth in rural Malawi: the Mazira Project randomized controlled trial. *The American journal of clinical nutrition*, 110(4), 1026-1033.

Link: <https://doi.org/10.1093/ajcn/nqz163>

This randomized control trial was conducted to assess the impact of the 1 egg per day intervention to improve child growth in rural Malawi. The study included 660 participants between the ages 6-9 months old who were split into either control groups or the one egg per day intervention group. The researchers visited homes twice per week for both groups while supplying eggs to homes with children within the intervention group during these visits. The length, weight, head circumference, mid-upper arm circumference was measured twice, once during baseline and the other in the 6th month follow up. Some of the factors within the study include maternal status that contains age, education, marital status, and other factors such as home environment, and diets. The study found that the intervention group saw a 3.9% rise in egg consumption while the control group stayed stagnant. Overall, there wasn't any significant length gain or risk of stunting for the group that consumed an egg per day. However, the researchers note that this lack of benefit could be due to an already rich diet from the consumption of fish. Some of the limitations within the study include the fact that egg consumption was reported and not observed which some households could have lied instead of feeding it to their children.

Thorne-Lyman, A. L., Shrestha, M., Fawzi, W. W., Pasqualino, M., Strand, T. A., Kvestad, I., ... and Miller, L. C. (2019). Dietary Diversity and Child Development in the Far West of Nepal: A Cohort Study. *Nutrients*, 11(8), 1799.

Link: <https://doi.org/10.3390/nu11081799>

This longitudinal cohort study of 395 children in rural Nepal investigates the diversity of diets that were consumed to identify the relationship between diet and child development in LMIC's. Developmental gains were identified using the Ages Stages questionnaire while the relationship between food groups and the number of days a child consumed a minimum diversity diet was assessed using a multiple linear and logistic regression. Some of the factors included in the study are minimum dietary diversity, socioeconomic status, consumption of fruits and vegetables, and maternal education. Children who consumed ASF, vegetables, and fruits earlier into their childhood achieved a better score

in developmental testing scores. The study also highlighted that maternal education had also been found to be related to a child's developmental outcome which lines with other studies that indicated that better maternal education led to a positive developmental outcome for their children. To maintain better growth and improve childhood development, a diverse diet including vegetables, fruits, and animal-source foods will need to be promoted especially with the expansion of processed food being introduced to Nepal. Some of the limitations within the study include a small sample size that produces uncertainties and the lack of validation for the age stages questionnaire to be used within the context of this study.

Workicho, A., Belachew, T., Ghosh, S., Kershaw, M., Lachat, C., and Kolsteren, P. (2018). Burden and determinants of undernutrition among young pregnant women in Ethiopia. *Maternal and child nutrition*, 15(3), e12751.

Link: <https://doi.org/10.1111/mcn.12751>

This study used a multivariable regression analysis to identify the severity and determinants of undernutrition and anemia within pregnant women in Ethiopia. The sample consisted of 1,393 pregnant women with all analyses performed using STATA version 14. Some of the factors considered in the study include demographic characteristics and family environment. Within the sample of pregnant women about 38% were undernourished and 22% were anemic. The study indicated that factors such as improved maternal education, increased wealth status, higher minimum dietary diversity, increased maternal height, and protected water sources all contributed to the decrease in the risk of undernutrition. On the other hand, unimproved toilets and depression increased the chances of anemia. The study also identifies that the incorporation of ASF into diets decreases the risk for both anemia and undernutrition. Although the consumption of ASF is difficult due to various factors that create barriers in LMIC's, incorporating even small amounts could be beneficial by providing essential micronutrients and protein. The study concludes by highlighting that young maternal age, poor health, and environmental condition are all important factors that could contribute to undernutrition and they push that for future programs working on maternal nutrition, the promotion of ASF is vital. Limitations within the study include small sample size and the inability to adjust some data that could underestimate some findings.

Additional Resources:

Adesogan, A. (2017, March). Feed the Future Innovation Lab for Livestock Systems: The imperative to increase animal-source food consumption. Nurturing development: Improving human nutrition with animal-source foods. Symposium conducted at the University of Florida, Gainesville, FL.

Allen, L. H., Black, A. K., Backstrand, J. R., Peltó, G. H., Ely, R. D., Molina, E., and Chávez, A. (1991). An analytical approach for exploring the importance of dietary quality versus quantity in the growth of Mexican children. *Food and Nutrition Bulletin*, 13(2), 95-104.

Allen, L. H. (2008, December). How common is vitamin B-12 deficiency? *The American Journal of Clinical Nutrition*, 89(2), 693S-698S. doi:10.3945/ajcn.2008.26947A

Allen, L. H. (2009). How common is vitamin B-12 deficiency? *The American journal of clinical nutrition*, 89(2), 693S-696S.

Arimond, M., and Ruel, M. T. (2004). Dietary diversity is associated with child nutritional status: evidence from 11 demographic and health surveys. *The Journal of nutrition*, 134(10), 2579-2585.

Bath, S., and Rayman, M. (2016). Iodine. In *Food Fact Sheet*: The British Dietetic Association.

Deegan, K. L., Jones, K. M., Zuleta, C., Ramirez-Zea, M., Lildballe, D. L., Nexø, E., and Allen, L. H. (2012). Breast milk vitamin B-12 concentrations in Guatemalan women are correlated with maternal but not infant vitamin B-12 status at 12 months postpartum. *The Journal of nutrition*, 142(1), 112-116.

- Givens, I. D., and Soedamah-Muthu, S. S. (2016). Dairy fat: does it increase or reduce the risk of cardiovascular disease? *The American Journal of Clinical Nutrition*, 104(5), 1191-1192. doi:10.3945/ajcn.116.144766
- Iannotti, L. (2017, March). Evidence for using animal-source foods to improve the growth and development of children. *Nurturing development: Improving human nutrition with animal-source foods*. Symposium conducted at the University of Florida, Gainesville, FL.
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Livestock Production and Human Nutrition

- Ahmed, M. M., Jabbar, M., and Ehui, S. (2000). Household-level economic and nutritional impacts of market-oriented dairy production in the Ethiopian Highlands. *Food and Nutrition Bulletin*, 21(4), 460-465.

Link: <https://doi.org/10.1177%2F156482650002100423>

The study took place in the Ethiopian highlands approximately 40 km west of Addis Ababa near the small town of Holetta. A total of 84 households were surveyed. Crossbred cows and feed technologies were introduced to create increased household income and expenditure on food and non-food and improve human nutrition. Human nutrition was measured by caloric intake. To obtain data for food intake, households were visited monthly and participants were asked to do a food recall. When compared to the control group, households who owned the crossbred cows had statistically significant higher intake of calories, fat, protein, retinol, and iron and a slight increase in carbohydrates, which was not statistically significant.

- Ayele, Z., and Peacock, C. (2003). Improving access to and consumption of animal source foods in rural households: The experiences of a women-focused goat development program in the highlands of Ethiopia. *The Journal of Nutrition*, 133(11S-II), 3981S-3986S.

Link: <https://doi.org/10.1093/jn/133.11.3981S>

The Dairy Goat Development Project worked with more than 5,500 female-headed households in the Oromia and southern region of Ethiopia. The project worked to improve the productivity of goats managed by women through better management techniques and genetic improvements. With regards to nutrition, the project aimed to increased consumption of milk by children to better their intake of vitamin A and zinc. The project also has a gender goal of empowering women through helping them develop leadership skills, improve their technical knowledge, and encourage them to diversity their activities for income. Pre- and post-data were collected on household milk consumption. There was an increase in caloric, protein, and fat intake as a result of the goat project.

- Choudhury, S., and Headey, D. D. (2018). Household dairy production and child growth: Evidence from Bangladesh. *Economics and Human Biology*, 30, 150-161.

Link: <https://doi.org/10.1016/j.ehb.2018.07.001>

In this study concerns about dairy producers differing from non-dairy households are investigated by applying a novel double difference model to data obtained in rural Bangladesh. The study separated the data into three groups of households 1) households that own cows that have produced milk, 2) a placebo group that has not produced milk in the past 12 months, 3) and the control group of household that do not own any cows. A regression model was used to control for household expenditures and wealth. Determinants of milk production were first assessed and then a multivariate reduced form regression to control for confounding factors. Children's total calorie consumption and a dietary diversity score (0-6 food groups) that excluded dairy were used to identify generic income-based pathways. Some of the factors included in the study are herd size, socioeconomic status, health production functions, and household characteristics. The study finds that a regular supply of dairy products or cattle ownership was crucial during 6-23 months of a child's life therefore a cow's milk is important for linear growth in children. Due to the low levels of dairy consumption, the study proposes

alternative options such as powdered milk or imported dairy or the implementation of rapid domestic production.

Darrouzet-Nardi, A. F, Miller, L. C., Joshi, N., Mahato, S., Lohani, M., and Rogers, B. L. (2016). Child dietary quality in rural Nepal: effectiveness of a community-level development intervention. *Food Policy*, 61, 185-197.

Link: <https://doi.org/10.1016/j.foodpol.2016.03.007>

The study was conducted in the districts of Chitwan, Nawalparasi, and Nuwakot in Nepal. Three other sites were chosen as a control group which would receive the intervention in the second year of the program. Females who were the head of their households were to complete a food recall for their children who were between 6 months and 8 years of age. The program was 12 months long and used Heifer curriculum on poverty alleviation, citizen empowerment, and community development with an emphasis on optimizing livestock to create income. At the end of the program, participants were given two meat goats. Dietary quality, which was the outcome of interest, were separated into measures of a dietary diversity score (DDS), a minimum dietary diversity (MDD), and whether children had consumed animal-sourced foods. A total of 180 intervention households and 184 control households were sampled. The children in the intervention group had improved dietary diversity score and minimum dietary diversity and an increased likelihood of consuming animal-source foods.

Hetherington, J. B., Wiethoelter, A. K., Negin, J., and Mor, S. M. (2017). Livestock ownership, animal source foods and child nutritional outcomes in seven rural village clusters in Sub-Saharan Africa. *Agriculture and Food Security*, 6(1).

Link: <https://doi.org/10.1186/s40066-016-0079-z>

This study examines the relationships between livestock ownership, animal source food consumption, and child nutritional outcomes across seven rural village clusters in Sub-Saharan Africa as a basis for informing future nutrition security and livestock-based interventions. The study analyzed data collected from year 3 of the Millennium Village Project from 2008 to 2009, and the seven clusters examined were Bonsaaso, Ghana; Mayange, Rwanda; Mwandama, Malawi; Tiby, Mali; Papaida, Nigeria; Potou, Senegal; and Ruhira, Uganda. At the time of this study, a few interventions had begun in the villages that likely affected nutritional status, but not livestock production or ASF consumption, including a school meal program and provision of fertilizer and seed varieties to increase crop yields. Data was collected through face-to-face interviews and information was gathered on household demographics, agriculture, and the health of mothers and children. Food insecurity status was measured by the number of months reported with inadequate food in the last 12 months, and livestock ownership was assessed based on whether a household owned one or more of: poultry, pigs, small ruminants, and cattle. The results demonstrated that 47% of households experienced at least one month of food insecurity. In turn, livestock ownership patterns were variable between village clusters, but overall, 77% of households owned one or more livestock group. The most commonly owned livestock group was poultry at 57%. Animal source food consumption had great variation between village clusters yet overall 61% of households consumed sheep or goat meat in part of meal or as their main meal in the past 30 days. This comparative and descriptive analysis of livestock ownership, ASF consumption, and child nutritional outcomes found some evidence that owning livestock increased household consumption of ASF but owning livestock and consuming ASF did not consistently have associations with improved child growth in any of the seven village clusters.

Hoddinott, J., Headey, D., and Dereje, M. (2013). Cows, Missing Milk Markets and Nutrition in Rural Ethiopia. *SSRN Electronic Journal*.

Link: <https://doi.org/10.1080/00220388.2015.1018903>

This paper tested the importance of cow ownership for nutrition in rural Ethiopia. The authors hypothesized that cow ownership is an important determinant of dairy consumption and linear growth and tested this using household survey data from Ethiopia. The authors adapted the standard agricultural household model to consider the dimensions of nutrition on both the topics of intake of foods and anthropometric status under complete and missing markets. The household decision-making process was also conceptualized to where parents are concerned about the nutritional status of preschool children and their nutrient intakes. The data was drawn from a household survey of the Government of Ethiopia's Agricultural Growth Program (AGP) in the four highlands of Ethiopia. The study's results supported the authors' hypothesis that cow ownership in underdeveloped rural settings drove the consumption of dairy products and drove linear growth of young children. The authors suggest that intervention can be implemented to increase cow ownership, increase dairy productivity, and to increase dairy market development due the results' suggestion that cattle ownership at the household level may have the largest short-term benefits in settings where markets are highly underdeveloped.

Jin, M., and Iannotti, L. L. (2014). Livestock production, animal source food intake, and young child growth: The role of gender for ensuring nutrition impacts. *Social Science and Medicine*, 105, 16-21.

Link: <https://doi.org/10.1016/j.socscimed.2014.01.001>

This study used pre-existing data collected in 6 provinces in Kenya, during a large-scale impact evaluation. The hypothesis tested was that female-owned/co-owned livestock would be associated with improvement in childhood growth, mediated by increased ASF consumption. Surveys were conducted and data was collected from September 2010 to January 2011. In regard to livestock, was discovered that female-owned/co-owned livestock were evaluated to have an average value of 18,861 Kenyan shillings, versus the average value of 66,343 Kenyan shillings for male-owned livestock. The portion of the study regarding childhood growth, had a sample size that included 183 children, aged 6-60 months. In an analysis, adjusted for caregiver education level, income, child age, and child sex, a multivariate linear regression model was conducted and results showed a positive association between the female-owned/co-owned livestock with the child's weight-for-age z score (WAZ). The results of a Sobel-Goodman test ($p < 0.05$) showed a mediating effect by child ASF intake, which rationalized 25% of the relationship between livestock ownership with child WAZ. Though no effect was found apparent between child weight-for-height z scores and female-owned/co-owned livestock, a "trend toward significance" was demonstrated for female-owned/co-owned livestock and height-for-age z scores. The authors discuss how the found mediating effect is likely indicative of other, interwoven factors that come with female-owned/co-owned livestock (i.e. more female input in household decisions, better understanding of ASF, more access to ASF and the person in charge of feeding the household, etc.) The large takeaway the authors state is that the results of their study suggest that the way to guarantee progresses in overall child nutrition through ASF is to target females in livestock production.

Jodlowski, M., Winter-Nelson, A., Baylis, K., and Goldsmith, P. D. (2016). Milk in the Data: Food Security Impacts from a Livestock Field Experiment in Zambia. *World Development*, 77, 99-114.

Link: <https://doi.org/10.1016/j.worlddev.2015.08.009>

The authors of this study use panel data from a Heifer International livestock program in Zambia to identify the causal effect of livestock ownership on dietary diversity and consumption expenditure. The analysis was done with 300 households over 18 months. Households were screened to remove the non-poor from the pool of livestock recipients so that households eligible for Heifer assistance are neither the poorest in Zambia nor are they wealthy. 72% of the participating households live on less than the equivalent of \$1.25USD per person per day and the participants have shown a willingness to

participate in organized groups with the purpose of access to livestock and were thus self-selected. There were three categories of surveyed households—Originals, Prospectives, and Pass-on-the-gift households (POG). Originals were households that received livestock in an initial distribution; POGs received the female offspring from the initially donated animals; and Prospectives were a control in that they were unserved groups. A final group was the “Independents,” who were not interested in or were incapable of participating in the program. The authors analyzed the effects of livestock on dietary diversity and consumption expenditure patterns using a difference-in-differences method, with household dietary diversity as a measure of food security and the sum of the probability of each food group being consumed in the last 24 hours based on the reported frequency of consumption over the last seven days to capture a dietary diversity score. The results of the regressions for these measures showed that for household dietary diversity, there was very little effect of livestock receipt on this measure, perhaps reflective of highly variable consumption throughout the week. For the DDS measure, there were significant positive effects of both dairy cows and goats, highlighting that the receipt of a dairy cow leads to 4.5 more days in which the household consumes an additional food group. Goats added 3 days of additional food consumption. Ultimately, the authors saw positive and significant results of livestock contribution to a higher DDS that were consistent across all models, emphasizing that owning dairy cows and goats have a positive, direct impact on the expected number of food groups eaten in a household. Therefore, expanded animal agriculture leads to increased food security through direct consumption of home-produced animal products.

Rogers, I., Emmett, P., Gunnell, D., Dunger, D., Holly, J., and the ALSPAC Study Team. (2005). Milk as a food for growth? The insulin-like growth factors link. *Public Health Nutrition*, 9(3), 359-368.

Link: <https://doi.org/10.1079/PHN2006853>

The purpose of the study was to research an association between consumption of cows' milk and dairy products with levels of insulin-like growth factor-1 (IGF-1), insulin-like growth factor-binding protein-3 (IGFBP-3), and height and leg length. The study took place in Avon County in South West England. A total of 1,432 children were randomly selected who were between 7-8 years of age. Diet was assessed using a dietary record; height and length were taken; IGF-I level were determined by radioimmunoassay through a monoclonal antibody and recombinant peptide. IGFBP-3 levels were determined by radioimmunoassay using a polyclonal antibody. Results found a positive association between milk and dairy products with IGF-1 and IGFBP-3 in all children. Dairy consumption was positively associated with leg length in boys. There was no association found with leg length in girls and so the analysis was repeated in girls less than 8 years old which found an inverse association.

Smith, J. (2017, March). The role of livestock in food and nutrition security. *Nurturing development: Improving human nutrition with animal-source foods*. Symposium conducted at the University of Florida, Gainesville, FL.

Link: [Smith](#)

The author presents that the demand for animal-source foods has been increasingly quickly in low- and middle-income countries. While livestock accounts for a large portion of the GDP in Africa, there is little public funding and development assistance given to these sectors. The issues of availability, accessibility, stability, and utilization of foods with adequate nutrition are those which make up food and nutrition insecurity. The high density of macro- and micronutrients animal-source foods contain are explained. The pathways in which livestock contribute to nutrition are highlighted such as by increasing production and thus incomes, increasing manure and animal traction and thus production, and providing steady income. The author notes that only a portion of smallholder livestock producers will succeed in market-oriented livelihoods and so it is important to help smallholders become “smartholders”.

Additional Resources:

- Ayalew, W., Gebriel, Z. W., and Kassa, H. (1999). Reducing vitamin A deficiency in Ethiopia: Linkages with a women-focused dairy goat farming project. Research Report No. 4. *Center for Research on Women (ICRW)/Opportunities for Micronutrient Interventions (OMNI)*, Washington, DC.
- Begum, J. M. (1994). The impact of dairy development on protein and calorie intake of pre-school children. *Indian Journal of Medical Science*, 48(3), 61–64.
- Galal, O. M., Harrison, G. G., Abdou, A. I., and Zein el Abedin, A. (1987). The impact of a small-scale agricultural intervention on socio-economic and health status. *Food and Nutrition*, 13(1), 35–43.
- Habtemariam, K., Ayalew, W., Habte, G. Z., and Gebre, M. T. (2003). Enhancing the role of livestock production in improving nutritional status of farming families: Lessons from a dairy goat development project in Eastern Ethiopia. *Livestock Research for Rural Development*, 15(6).
- Nielsen, H. (1996). The socio-economic impact of a smallholder livestock development project, Bangladesh, integrated farming in human development (workshop). *Danish Agricultural and Rural Development Advisers Forum*
- Tangka, F., Ouma, E. A., and Staal, S. J. (1999). Women and the sustainable development of market-oriented dairying: Evidence from the highlands of East Africa. *International Sustainable Development Research Conference*

Risks within ASF Consumption**Livestock Ownership and Hygiene Habits**

- De Bruyn, J., Thomson, P. C., Darnton-Hill, I., Bagnol, B., Maulaga, W., and Alders, R. G. (2018). Does village chicken-keeping contribute to young children's diets and growth? A longitudinal observational study in rural Tanzania. *Nutrients*, 10(11), 1799.
Link: <https://doi.org/10.3390/nu10111799>

In this longitudinal study, a multivariable mixed model analysis used the demographic, socioeconomic, and livestock-associated variables of households to identify its association with maternal and child diets, children's height-for-age, and finally children's diarrhea frequency. The study took place in Manyoni District, Tanzania which included 503 households, all of which had a child under 24 months. Some of the factors within the study include demographic characteristics, water and sanitation, and chicken housing practices. There was no association found between chicken ownership and egg consumption in the study but an association between wealth and egg consumption was indicated. Other studies across different regions in Africa have found a similar correlation due to the monetary value of selling eggs in the market. More than a third of the households that kept chicken participated in the practice of keeping their chicken inside the house during the night. The study does indicate that children reported diarrhea after previously consuming milk from their cattle which is predicted to have been a contamination of the milk itself by zoonotic pathogens or aflatoxins and not from chickens. The study concludes that chicken ownership did lead to higher consumption of ASF and there was no greater risk of stunting or diarrhea with free-roaming chickens within this study. Some limitations in the study included high attrition rates due to the lack of rainfall that forced many to relocate and the bias that was incorporated with the self-reporting of diarrhea.

- Christian, A. K., Wilson, M. L., Aryeetey, R. N., and Jones, A. D. (2019). Livestock ownership, household food security and childhood anaemia in rural Ghana. *PLOS ONE*, 14(7), e0219310.
Link: <https://dx.doi.org/10.1371/journal.pone.0219310>

This cross-sectional study implements a community-based survey of 300 households in southern Ghana to identify the relationship between household anemia among children that are 2-5 years old and livestock ownership. Anemia was defined by having a hemoglobin concentration of less than 100 g/L and ASF consumption was defined as the number of different types of ASF consumed within the week prior to the interview. Some of the factors considered in the study include household food security and consumption of ASF. There was no evidence that the consumption of ASF mediated the relationship with owning livestock and anemia, but ownership did mediate the relationship between pig ownership and anemia. There was also an association between Malaria and Anemia, but the study wasn't able to establish whether the children received anemia due to malaria or household livestock due the cross-sectional nature of the study. The odds of having anemia was also greater with the ownership of free-range chicken, but the study found no association between ownership of free-range chicken and intestinal parasitic infections. While there was a greater household food security and consumption of ASF within the household that owed livestock there was however an increased likelihood of anemia among children in the household.

George, C. M., Oldja L., Biswas, S. K., Perin, J., Lee, G. O., Ahmed, S., ... and Faruque, A. G. (2015) Fecal markers of environmental enteropathy are associated with animal exposure and caregiver hygiene in Bangladesh. *American Journal of Tropical Medicine and Hygiene*, 93(2), 269–75.

Link: <https://doi.org/10.4269/ajtmh.14-0694>

This is a cross-sectional study of 216 randomly selected children in the Tangail district of Bangladesh. The aim of the study was to determine if unsanitary home conditions play a role in environmental enteropathy (EE) and stunting in children due to exposure to enteric pathogens. The authors highlighted the lack of attention being given to household environmental conditions and their relationship to markers of EE. The researchers examined the environmental conditions of the household, hand cleanliness, collected stool samples from children, and measured weight and height. Specific livestock indicators were used as determinants—the presence of animals in and around the home and the location of an animal corral. An EE disease activity score was calculated from fecal myeloperoxidase, alpha-1-antitrypsin, and neopterin. The article showed that children living in a household with an animal corral in the room they slept in had significantly higher EE scores than those children who slept in a room without an animal corral. The article concluded that household environmental conditions, specifically livestock hygiene conditions, play a role in EE and stunting in children, and specifically that a child's odds of being stunted were significantly by sleeping in rooms with an animal corral.

Gelli, A., Headey, D., Becquey, E., Ganaba, R., Huybregts, L., Pedehombga, A., ... and Verhoef, H. (2019). Poultry husbandry, water, sanitation, and hygiene practices, and child anthropometry in rural Burkina Faso. *Maternal and child nutrition*, e12818.

Link: <https://doi.org/10.1111/mcn.12818>

In this study data from a cross-sectional survey was analyzed to assess the relationship between poultry, water, sanitation, and hygiene practices, and anthropometric indicators in 3,230 children who were 6-59 months old living in Burkina Faso. The study used a multilevel regression to incorporate for hierarchical nature of the data that were accumulated through household surveys. Surveys were collected in three regions of Burkina Faso using a structured questionnaire that gathered all anthropometric data of children (under 5 years) and women of childbearing age (15-35 years). Some of the factors within the study include household poultry production and poultry consumption in young children, children's exposure to poultry feces, presence of poultry feces in spaces shared between children and poultry, and WASH interventions. The results showed observable health risks that were related to poultry flock size and poultry-husbandry practices. Poultry was also associated with having

lower hygiene levels. WASH environment was also related to child anthropometric indicators which showed evidence that getting water from a borehole compared to having unsafe and unprotected water sources led to greater height-for-age z scores. Some of the limitations in the study include how the sample population wasn't representative for the Burkinabe population being studied, and due to the observational nature of the study, only a few associations could be inferred, and bias could have been generated by the enumerators.

Grados, O., Bravo, N. Black, R. E., and Butzler, J. P. (1988). Paediatric campylobacter diarrhea from household exposure to live chickens in Lima, Peru. *Bulletin of the World Health Organization*, 66(3), 369-374.

Link: <https://www.ncbi.nlm.nih.gov/pubmed/3262442>

The article explains that *Campylobacter jejuni* has been well-researched in its association to human enteric disease. The researchers seek to identify risk factors and modes of transmission through a case-control study. Participants were chosen from those presenting with acute diarrhea at San Juan de Dios Hospital, Callao, and at Maria Auxiliadora Hospital, Villa Maria del Triunfo. The researchers sampled 1,290 stool samples and 104 of them had *C. jejuni* or *Campylobacter coli*, which were chosen as the cases. Results showed a direct correlation to sick individuals and time spent in contact with chickens, with a high likelihood that more of those chickens were infectious. Additionally, the households with more chickens had a higher count of infected chickens than households in the control group. Thus, ill-individuals were more likely to come from households keeping chickens than to come from the control group. The ill-individuals came from households who more frequently kept chickens than the control group. The article concluded that the strongest risk factor for becoming ill was cohabitating with chickens infected with *C. jejuni* in the same household.

Headey, D., and Hirvonen, K. (2016). Is exposure to poultry harmful to child nutrition? An observational analysis for rural Ethiopia. *PLOS ONE*, 11(8), e0160590.

Link: <https://doi.org/10.1371/journal.pone.0160590>

The article illustrates that much research has been done on the importance of animal-sourced foods for nutrition, including through the role of livestock; however, no research has been conducted to determine the risks of gastrointestinal or respiratory infections due to livestock ownership. There have been associations between exposure to livestock and diarrhea, and it has been hypothesized that the high prevalence of animal feces in developing nations may increase the risk for environmental enteric dysfunction (EED) and stunting. This article emphasizes the neglect of studying animal feces in WASH, health, and nutrition, and argues that agricultural interventions must be reconsidered given that exposure to animal feces is often a widespread occurrence in households of developing countries. The article tested the hypothesis that poultry ownership in Ethiopia had a negative association with stunting (height-for-age Z scores [HAZ]), due to an increased exposure to pathogens from livestock. The research was conducted through an explanatory analysis and no biomarkers of EED were used. The study collected surveys from 6,977 households in the five largest regions of Ethiopia (Amhara, Oromia, Somali, Southern Nations, Nationalities, and Peoples' Region [SNNP] and Tigray). These regions were studied because they were to receive investments to improve agricultural production and nutrition from the Feed the Future United States Agency for International Development (USAID) program. The survey allowed for the linkage of the quality of food consumed and anthropometry. The outcome of interest was HAZ. The study concluded that those who kept poultry outside had better nutritional outcomes compared to households which kept poultry inside. Results from the study suggest that poultry-related hygiene issues are an important factor to consider when researching the dynamic relationship between poultry ownership and child nutrition.

Jones, A. D., Colecraft, E. K., Awuah, R. B., Boatemaa, S., Lambrecht, N. J., Adjorlolo, L. K., and Wilson, M. L. (2018). Livestock ownership is associated with higher odds of anaemia among preschool-aged children, but not women of reproductive age in Ghana. *Maternal and child nutrition*, 14(3), e12604.

Link: <https://doi.org/10.1111/mcn.12604>

In this study, investigators assessed the relationship among household livestock ownership to identify any contributors to ASF with anemia. The study focused on women from 15-49 years of age and children who were 6-59 months of age in Ghana. Data was collected from the 2014 Ghana Demographic and Health Survey and the Ghana Living Standards Survey Round 6. From these sources data from 4,441 women, 2,735 children, and 16,772 households were analyzed by using a multiple logistic regression model. Some of the factors that were included in the study include hemoglobin measurements, household levels, food group intake, food consumption, and food expenditure. The study finds that although there was a strong correlation between livestock ownership and anemia among children, it was not the case for women. This relationship was the same as chickens. While chicken ownership had produced a high association with anemia among children, there was once again no association among women. Some of the limitations incorporated within the study included problems like how the data were observational and collected at a single time point, and how the 2014 GDHS that produced the dietary data were limited to a qualitative assessment of food group diversity among a small population of children.

Kaur, M., Graham, J. P., and Eisenberg, J. N. (2017). Livestock Ownership Among Rural Households and Child Morbidity and Mortality: An Analysis of Demographic Health Survey Data from 30 Sub-Saharan African Countries (2005-2015). *Am J Trop Med Hyg*.

Link: <https://doi.org/10.4269/ajtmh.16-0664>

This cross-sectional study (2005-2015) examined the relationship between rural child health and ownership of livestock using DHS data conducted in 30 Sub-Saharan African countries. The goal was to assess children living in homes with livestock to understand two key components—the risk of enteric infections, and improved nutritional status from increased access to food, specifically ASF. Authors used logistic regression analyses on each country (and meta-analyses to combine all countries results) to estimate the relationship between a log2 increase in the number of livestock owned by the household and three child-health outcomes:

1. 2-week prevalence of diarrhea
2. Stunting
3. All-cause mortality

The results indicated significant heterogeneity by country, indicating that more data is needed to understand the specifics in household but were consistent with the association that livestock may have a dual role as protective against stunting, an indicator of chronic malnutrition, and a risk factor for all-cause mortality in children, which may be linked to acute infections and diarrhea. For a majority of the countries analyzed findings showed:

1. Stunting
 - a. 22 of 30 countries displayed an odds ratio OR <1.0 for child stunting associated with livestock, indicating ownership of livestock was protective against stunting (pooled OR = 0.97; 95% confidence interval [CI] = 0.95, 0.99).
 - b. 6 countries (Senegal, Guinea, Congo, Mali, Nigeria, and Gabon) showed OR > 1.0 for child stunting associated with livestock ownership.
2. Diarrhea
 - a. 13 countries displayed OR >1.0 for diarrhea associated with livestock ownership.
 - b. 7 countries displayed OR < 1.0 for diarrhea associated with livestock ownership.

c. Results indicate that there is not a clear pattern for child diarrhea risk for households that own livestock

3. Child Mortality

a. 22 of 30 countries displayed an OR > 1.0 for child mortality (pooled OR = 1.04; 95% CI = 1.02, 1.06).

b. Kenya showed the strongest protective effect of livestock toward mortality (OR = 0.90, 95% CI = 0.83, 0.99)

c. Liberia showed the strongest odds for mortality associated (OR = 1.19, 95% CI = 1.10, 1.29), suggesting a 19% increased odds of mortality associated with a doubling of livestock ownership.

Lambrecht, N. J., Wilson, M. L., and Jones, A. D. (2019). Assessing the Impact of Animal Husbandry and Capture on Anemia among Women and Children in Low- and Middle-Income Countries: A Systematic Review. *Advances in Nutrition*, 10(2), 331-344.

Link: <https://doi.org/10.1093/advances/nmy080>

In this systematic review paper, the relationship between animal husbandry and capture (AHC) and anemia among three groups of people in LMICs were assessed. The groups that were investigated included women in reproductive age, school-aged children, and children who were under the ages of 5. Observational studies assessing animal-dependent livelihood and livestock ownership as well as programs that supported livestock and fish production were incorporated within the study. First, a 2-stage screening process was used which yielded to a total of 23 papers implemented in the final review. Some of the factors within the study were the livelihood of families and the various interventions within the studies. The results showed inconsistencies between AHC exposure and its population groups. While children showed fewer signs of anemia in nomadic pastoral communities, anemia was prevalent in women who lived in the same communities. Although the study indicates that the source of anemia is still unknown, they emphasize that both women and children greatly benefitted from the programs that combined animal production with education and gardening components. Poultry was frequently promoted by interventional studies because of it was accessible, affordable, and was able to be sold by women, but observational studies have shown some opposition towards this because of the positive relationship between chicken ownership and anemia among children. In the end, the study concludes that livestock can lead to alleviating undernutrition among the poor, but it was necessary to continue to look at the risks associated with animal production. Some of the limitations within the study include an inappropriate control group, lack of control for confounding bias, and insufficient statistical power.

Li, M., Havelaar, A. H., Hoffmann, S., Hald, T., Kirk, M. D., Torgerson, P. R., and Devleesschauwer, B. (2019). Global disease burden of pathogens in animal source foods, 2010. *PLOS ONE*, 14(6), e0216545.

Link: <https://doi.org/10.1371/journal.pone.0216545>

In this study, the disease burden associated with ASF was investigated by focusing on estimates of 13 pathogens that were obtained from the global burden of foodborne disease (FBD) of the WHO Foodborne Disease Burden Epidemiology Reference Group (FERG). Three groups of estimates were combined to identify the disease burden of ASF food groups based on different regions around the world. The proportion of disease transmitted by eight groups of ASF was added to the estimates calculating FBD burden and uncertainty was accounted by using Monte Carlo simulations. Some of the factors considered in this study are food safety, food control systems, food hazards, pathogens, ASF, FBD, and FERG. The study found that 70% of the burden caused by ASF was due to three pathogens: NTS, *T. solium*, and *Campylobacter*. It also identified that out of all FBD caused by the 13 pathogens that were analyzed within this study, a third of the cases were caused by ASF. All of the proportions for FBD that were associated with ASF were highly variable between subregions and

countries. Pathogens such as NTS, *Campylobacter* spp. And *T. gondii* have been distributed globally and in turn affected FBD burden globally in the global north and south. A limitation encountered in the study was the lack of available data for low-income countries. Although these gaps in data were filled, it heightened the uncertainty of the analysis. Some FBD burden estimates were also unable to be included where ASF was very imported due to the prevalence of some pathogens in the environment.

Marquis, G. S., Ventura, G., Gilman, R. H., Porras, E., Miranda, E., Carbajal, L., and Pentafiel, M. (1990). Fecal contamination of shanty town toddlers in households with non-corralled poultry, Lima, Peru. *American Journal of Public Health*, 80(2), 146–9.

Link: <https://doi.org/10.2105/AJPH.80.2.146>

The article highlights the knowledge gap in research on the prevalence of *Campylobacter jejuni* in chickens, arguing this bacterium is of specific interest as it contributes to high cases of diarrhea and may lead to EED infections in children. Participants included 21 toddlers from 10 families from two shanty towns of Huascar, Canto Grande and Las Pampas de San Juan, San Juan de Miraflores in Lima, Peru. The researchers observed toddlers for 12 hours to determine the rate at which they were contaminated with feces from infected animals. Findings concluded that it was common for toddlers to become contaminated with feces of animals owned by the household, and that toddlers were not likely to wash their hands after contamination. The article suggests effective interventions may include challenging beliefs that chickens do not spread disease, as well as encouraging households to corral animals to mitigate contamination with feces.

Ngure, F., Gelli, A., Becquey, E., Ganaba, R., Headey, D., Huybregts, L., ... and Zongrone, A. (2019). Exposure to Livestock Feces and Water Quality, Sanitation, and Hygiene (WASH) Conditions among Caregivers and Young Children: Formative Research in Rural Burkina Faso. *The American journal of tropical medicine and hygiene*, 100(4), 998-1004.

Link: <https://doi.org/10.4269/ajtmh.18-0333>

This study investigates the households of young children and mothers to identify any health risks through a nutrition-sensitive poultry intervention in rural Burkina Faso. This was a five-week study that used a mixed-methods approach of combining both qualitative and quantitative methods that used in-depth interviews, direct observations, and focuses group discussions. Some of the factors included in the study are caregiver-child dyads, livestock, and WASH-related behaviors. In particular, the exposure to feces from livestock as well as WASH condition among children and caregivers were assessed. Although households were aware of health risks due to sanitation, poor child feces disposal, and handwashing practices were continued. The study indicated the difficulty of separating chickens from their children due to cost barriers that were nearly impossible to overcome in LMIC's. Cost is also a barrier when it came to poor hand sanitation because it prevented individuals from prioritizing soap and water. Fecal contamination within the house from livestock was a prevalent issue especially for young children with weaker immune systems. The study pushed for the incorporation of WASH-sensitive livestock management with ASF promotions to keep children safe. This promotion consists of changing perception by creating disgust, spreading awareness of the dangers associated with feces and pathogens that spreads from livestock, and providing safer disposable methods for fecal matter. The limitations within the study include a small sample size for in-depth observations and the likelihood of response biases about the questions pertaining to WASH and childcare practices.

Schmidt WP, Boisson S, Routray P, Bell M, Cameron M, Torondel B, et al. (2016) Exposure to cows is not associated with diarrhoea or impaired child growth in rural Odisha, India: a cohort study. *Epidemiol Infect.* 2016;144(1):53-63.

Link: <https://doi.org/10.1017/S0950268815001090>

This cohort study explored the effect of cow exposure on the growth and endemic diarrhea in children under 5 in rural and low-income India, and shows dissenting results from other studies listed in this annotated bibliography. The cohort clusters were randomly chosen within the district of Puri, in the state of Odisha, India. The study ran from September of 2010 until October 2013. The study population included 100 rural villages gathered from 7 of the 11 districts within Puri. Between September and October 2010, a baseline survey was conducted that included household demographics, cow ownership, structure of home, type of fuel used for cooking, and sanitation and water access. In 2011, an intervention of latrine construction was carried out in half of the villages, which required a child aged under 4 to participate. A second survey was conducted between December 2012 and March 2013 that assessed compliance with the intervention, as well as recorded the proximity of a cowshed to the house. Additionally, visits were made to households with children under the age of 5, every 3 months, where observers watched the child(ren) of the home's behavior and questioned the primary caregiver on diarrheal activity within the past 7 days. Results showed that 44% of households did not own cows; however, that the correlation of cowsheds within a 50m radius of the house was highly correlated to the population density. The results found that the presence of a cowshed within 50m of the home, use of cow dung for cooking, or cow ownership did not significantly increase any childhood growth or diarrheal presence. The inclusion of cowsheds outside of the 50m radius may have affected the results include that, regardless of having the precise GPS locations of homes and cowsheds. The authors state that the number of cowsheds around each home household, as a means of calculating cow population density; however, this was not the same for human population density. Additionally, there is no mention of surveys being conducted between the initial survey and the implementation of the latrine intervention on the diarrheal prevalence within children under 5 years of age. It is a possible that latrine access is a confounding factor, but the results cannot show the impact of the latrine intervention, because no baseline diarrheal data was taken.

- Wardrop, N. A., Hill, A. G., Dzodzomenyo, M., Aryeetey, G., and Wright, J. A. (2018). Livestock ownership and microbial contamination of drinking-water: Evidence from nationally representative household surveys in Ghana, Nepal and Bangladesh. *International Journal of Hygiene and Environmental Health*, 221(1), 33–40.**
Link: <https://doi.org/10.1016/j.ijheh.2017.09.014>

This article investigated the importance of animal feces in drinking water contamination. Specifically, the authors looked at the relationship livestock ownership and point of consumption drinking water contamination-using data from nationally representative household surveys in Nepal, Bangladesh, and Ghana. The authors used multinomial regression analyses, to adjust for potential confounders associated with water quality assessments, to assess the relationship between livestock ownership and the level (no, medium and high) of contamination with *E. coli* bacteria. The results indicated that owning livestock was a significant risk factor for the contamination of drinking water at the point of consumption. Specific results indicate that owning 5 or more large livestock was significantly associated with drinking water contamination in Ghana and Bangladesh. Study findings showed that in Bangladesh, owning 8 or more poultry livestock was associated with drinking water contamination.

- Zambrano, L. D., Levy, K., Menezes, N. P., and Freeman, M. C. (2014). Human diarrhea infections associated with domestic animal husbandry: A systematic review and meta-analysis. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, 108(6), 313-325.**
Link: <https://doi.org/10.1093/trstmh/tru056>

This article is a good resource as a quick reference to animal-specific pathogens and diarrheal illness relevant to livestock ownership. The authors conducted a systematic review of literature, in search for evidence of an associative, and causal, relationship between livestock ownership and cases of human diarrhea and enteric infections. A total of 29 studies were reviewed and examined for results. The reviewers found a positive association between food-producing animal exposure and diarrheal illness

among the various animals and pathogens examined. Additionally, 21 of the 29 studies denoted a positive association for at least one animal-pathogen pair. The document contains a list of the pathogens identified from the studies, as well as the corresponding host animal within which the pathogen was found. A total of 10 studies identified *Campylobacter spp.* as a pathogen linked to domestic animal husbandry—seven were identified with poultry, one with swine, one with goat/sheep, and one with an unspecified animal. The association between exposure to poultry and *Campylobacter* infection had an odds ratio of 2.73, showing that those keeping poultry were 2.73 times more likely to become infected with *Campylobacter spp.* than those who did not keep poultry.

Additional Resources:

Guerin MT, Martin W, Reiersen J, Berke O, McEwen SA, Bisaillon JR, et al. (2007). House-level risk factors associated with the colonization of broiler flocks with *Campylobacter spp.* in Iceland, 2001 - 2004. *BMC Veterinary Research*. 2007;3.

ASF Consumption and Environmental Enteric Dysfunction

Acosta, A. M., Chavez, C. B., Flores, J. T., Olotegui, M. P., Pinedo, S. R., Trigoso, D. R., ... and Bhutta, Z. A. (2014). The MAL-ED study: a multinational and multidisciplinary approach to understand the relationship between enteric pathogens, malnutrition, gut physiology, physical growth, cognitive development, and immune responses in infants and children up to 2 years of age in resource-poor environments. *Clinical Infectious Diseases*, 59(suppl 4), S193-S206.

Link: <https://doi.org/10.1093/cid/ciu653>

The multisite birth cohort study (MAL-ED) study focuses on birth cohorts followed longitudinally (to 24 months of age) in each of the 8 study sites. The central hypotheses being that:

- Enteropathogens contribute to stunting, wasting and micronutrient deficiencies.
- Enteropathogen infections cause intestinal inflammation and diminish the effectiveness of the barrier and absorptive function of the gut.
- In children under 2 years, gut dysfunction associated with enteric infections and undernutrition results in reduced nutrient absorption from the gut, growth faltering, cognitive impairments, and impaired responses to childhood vaccines.

The ultimate goal of the research being to design interventions to improve childhood growth and development and minimize the lost lifetime potential. The 8 field sites for the study are all located in resource-constrained areas, across 3 continents, and include both urban and rural communities with a history of high incidence of diarrheal disease and malnutrition. The field sites are located in Dhaka, Bangladesh; Fortaleza, Brazil; Vellore, India; Bhaktapur, Nepal; Loreto, Peru; Naushahro Feroze, Pakistan; Venda, South Africa; and Haydom, Tanzania. At enrollment, each child's demographics, information regarding initiation of breastfeeding, the child's length, weight, and head circumference were measured. Active surveillance for infectious diseases, general child health information, and basic dietary intake was undertaken by visiting each home twice per week. Additional visits were made to collect data about health, vaccinations, and dietary intake, and to measure anthropometry, perform cognitive tests, and collect blood, urine, and monthly surveillance (non-diarrheal) and diarrheal stool samples. Maternal and household characteristics were also recorded during this study.

The aim of MAL-ED is to improve scientific understanding of the complex interrelationships/synergies between: Gut microbial ecology, enteropathogen infection, dietary intake, nutritional status, gut physiology, growth, immune function and vaccine response, and cognitive development.

The primary health outcomes are: physical growth, cognitive development, and immune responses to oral and parenteral vaccines.

Amour C, Gratz J, Mduma E, Svensen E, Rogawski ET, McGrath M, et al. (2016) Epidemiology and Impact of Campylobacter Infection in Children in 8 Low-Resource Settings: Results From the MAL-ED Study. Clin Infect Dis. 2016;63(9):1171-9.

Link: <https://doi.org/10.1093/cid/ciw542>

This study describes the epidemiology and impact of campylobacter infection in the first 2 years of life in the MAL-ED study children (8 sites across 3 continents). Stools were collected from both diarrheal and non-diarrheal samples of children actively followed up until 2 years of age. A total of 1892 children had 7601 diarrheal and 26 267 non-diarrheal stool samples tested for *Campylobacter*. These stools were tested by enzyme immunoassay (EIA) for *Campylobacter* (ProSpecT) as well as *Giardia* and *Cryptosporidium* (TechLab) and blood samples were assayed for markers of intestinal permeability and inflammation (specifically, these tests include: myeloperoxidase--a marker of neutrophil activity in the intestinal mucosa (Alpco); neopterin--a marker of T-helper cell 1 activity (GenWay Biotech); and α -1-antitrypsin--a marker of intestinal permeability (Biovendor). Blood samples collected at 7, 15 and 24 months were tested for α -1-acid glycoprotein--a marker of systemic inflammation). The results indicate that there is a high prevalence, most children ($n = 1606$; 84.9%) having a *Campylobacter*-positive stool sample by 1 year of age, of *Campylobacter* infection and a negative association between *Campylobacter* burden and linear growth that is consistent across sites and persists after adjusting for potential confounders. The second half of the first year of life seems the most critical period for *Campylobacter*-associated growth faltering, with a large increase in *Campylobacter* prevalence during that time period. Despite site heterogeneity, protective factors associated with reduced *Campylobacter* detection included: exclusive breastfeeding (risk ratio, 0.57; CI, .47–.67), treatment of drinking water (0.76; 0.70–0.83), access to an improved latrine (0.89; 0.82–0.97), and recent macrolide antibiotic use (0.68; 0.63–0.74).

Crane, R. J., Jones, K. D., and Berkley, J. A. (2015) Environmental enteric dysfunction: an overview. Food and Nutrition Bulletin, 36(1), S76-87.

Link: <https://doi.org/10.1177/02F15648265150361S113>

The researchers conducted a search of papers and research relation to environmental enteric dysfunction (EED) between 1966 and June 2014. Sources used include PubMed, ClinicalTrials.gov, the WHO Clinical Trials Registry, the Cochrane Library, hand searches of literature retrieved, discussions with experts in the field, and personal experiences in the field. The article highlights the impact of EED on nutrition and development and immunity. The article also explains current methods of diagnosing EED including dual sugar absorption tests and biomarkers. The biomarkers currently used to measure gut inflammation are from the feces which include calprotectin; myeloperoxidase, neopterin, and α -1-antitrypsin; mRNA; REG1b; and lactoferrin. Biomarkers of gut permeability in the blood include zonulin, EndoCAb, and soluble CD14. Citrulline is a marker of total enterocyte mass. The article mentions the epidemiology and etiology of EED. Explanations of the causal factors of nutritional deficiency such as zinc or vitamin A and efforts to improve digestibility of food through fermentation, hydrolysis, or enzyme supplementation or enhancing amino acid profiles to reduce gut inflammation and improve repair. The effect of microorganisms on EED was specifically mentioned through fecal-oral exposure and how WASH can be of influence. Specific pathogens explained that may cause infection include *Cryptosporidium*, amoeba, roundworm, hookworm, *E. coli*, *Citrobacter rodentium*, *Giardia duodenalis*, and rotavirus. An imbalance of gut organisms is also a potential causal factor; the article details how *Helicobacter pylori* can influence small intestinal bacterial growth. The article briefly mentions the presence of HIV and EED simultaneously in infected populations. The paper provides a table of treatments that have been used in trials and provides points for future priorities.

Denno, D. M., VanBuskirk, K., Nelson, Z. C., Musser, C.A., Hay Burgess, D. C., and Tarr, P.I. (2014) Use of the lactulose to mannitol ratio to evaluate childhood environmental enteric dysfunction: a systematic review. Clinical Infectious Diseases, 59(4), S213-219.

Link: <https://doi.org/10.1093/cid/ciu541>

The researchers conducted a systematic review of the literature pertaining to biomarkers or diagnostic tests that have an association with mucosal dysfunction of the small intestine or host inflammation in small children published between 2000 and 2010. A total of 25 studies measured the lactulose to mannitol ratio (L:M), which is used to measure the absorption in the gut, as well as “gut leakiness”. Most studies found an increase or abnormal L:M value but comparing studies was difficult given differences in reporting of measures, specifically in Asia and West Africa. Some studies from South America and South Africa found normal L:M values. Five out of eight studies that research the association between L:M and growth found significant inverse relationships. The paper lists instances where L:M was used as an endpoint in studies and studies which found associations (or lack of) between other markers. A key result was the lack of standardization of procedures and reporting differed greatly between studies. The author concludes that the L:M is unlikely to be an adequate biomarker test by itself and an “enteropathy index” should be developed.

Donowitz, J.R., Haque, R., Kirkpatrick, B.D., Alam, M., Lu, M., Kabir, M., . . . Petri, W. (2016) Small intestine bacterial overgrowth and environmental enteropathy in Bangladeshi children. *Mbio*, 7(1), 1-7

Link: <https://doi.org/10.1128/mBio.02102-15>

The researchers conducted a cross-sectional analysis of 90 children aged 2 from a cohort of 700 children that were followed since birth from Dhaka, Bangladesh. The primary objective of the study was to determine prevalence of small intestinal bacterial overgrowth (SIBO) in the children; this was measured by a glucose hydrogen breath test. A secondary objective was to measure intestinal inflammation, intestinal permeability, and systemic inflammation. Intestinal inflammation was measured by fecal Reg 1 β and fecal calprotectin by enzyme-linked immunosorbent assay. Intestinal permeability was measured by a L/M ratio assessed by urinary analysis. Systemic inflammation was measured by C-reactive protein and a Luminex cytokine panel, granulocyte-macrophage colony-stimulating factor, gamma interferon, interleukon-1 β , monocyte chemoattractant protein, macrophage inflammatory protein 1 β , and tumor necrosis factor alpha. Findings included that SIBO was associated with concomitant intestinal inflammation but not increased intestinal permeability or systemic inflammation.

Fregonese, F., Siekmans, K., Kouanda, S., Druetz, T., Ly, A., Diabaté, S., and Haddad, S. (2017)l. Impact of contaminated household environment on stunting in children aged 12–59 months in Burkina Faso. *Journal of Epidemiology and Community Health*, 71(4), 356-363.

Link: <http://dx.doi.org/10.1136/jech-2016-207423>

This study used a longitudinal design by collecting data between 2011 and 2014 from the Kaya Health and Demographic Surveillance System (HDSS). Households were surveyed once a year and in 2014, the researchers conducted a survey on environmental conditions among 1,435 households through direct observation and a questionnaire. Data measured included episodes of illness, growth, and health among children. Findings included an increased prevalence of stunting among households with contaminated environments, low food security, no education, and agriculture was the main source of income and were in rural and peri-urban settings. Those children from contaminated households had a relative risk of 1.3 of stunting.

Guerrant RL, Leite AM, Pinkerton R, Medeiros PH, Cavalcante PA, DeBoer M, et al. (2016). Biomarkers of Environmental Enteropathy, Inflammation, Stunting, and Impaired Growth in Children in Northeast Brazil. *PLOS ONE*. 2016;11(9):e0158772.

Link: <https://doi.org/10.1371/journal.pone.0158772>

This study (also part of broader MAL-ED study) examined potential biomarkers that might associate functional and structural “enteropathy” with malnutrition or with subsequent growth impairment in children. The study enrolled children with malnutrition at a nutrition clinic serving several impoverished communities in and near Fortaleza, Ceará in Northeast Brazil. The goal of establishing a set of biomarkers is to predict both EED, and the implication for use to evaluate longer term growth and developmental impacts, and interventions designed to ameliorate these mechanisms and improve clinical outcome. The authors assessed potential plasma, urine and fecal biomarkers of intestinal epithelial or barrier disruption, evidence of bacterial product translocation and intestinal and systemic inflammatory responses, and intestinal permeability. A total of 402 children aged 6–26 months (201 malnourished and 201 age- and gender-matched, non-malnourished) were enrolled between August 30, 2010 and July 12, 2013; 375 provided fecal and blood samples and completed a lactulose-mannitol absorption test, and were asked to return for follow up in 2–6 months. Of these, 301 of these children returned for follow-up anthropometry after 2–6 months. Biomarkers that correlated with stunting included plasma IgA anti-LPS and anti-FliC, zonulin (if >12m old), and intestinal FABP (I-FABP, suggesting prior barrier disruption); and with citrulline, tryptophan and with lower serum amyloid A (SAA) (suggesting impaired defenses). In contrast, subsequent growth was predicted in those with higher fecal MPO or A1AT and by higher L/M, plasma LPS, I-FABP and SAA (showing intestinal barrier disruption and inflammation). Better growth was predicted in girls with higher plasma citrulline and in boys with higher plasma tryptophan. Interactions were also seen with fecal MPO and neopterin in predicting subsequent growth impairment. The authors conclude that key noninvasive biomarkers of intestinal barrier disruption, LPS translocation and of intestinal and systemic inflammation may help recognize, understand, and assess effective interventions for enteropathy and its growth and developmental consequences in children in impoverished settings.

Harper, K. M., Mutasa, M., Prendergast, A. J., Humphrey, J., and Manges, A. R. (2018). Environmental enteric dysfunction pathways and child stunting: A systematic review. *PLOS Neglected Tropical Diseases*, 12(1).

Link: <https://doi.org/10.1371/journal.pntd.0006205>

EED is commonly defined as “an acquired subclinical disorder of the small intestine characterized by villous atrophy and crypt hyperplasia,” and it is proposed to underlie stunted growth among children in developing countries. This study is a systematic literature review looking at studies from 2010–2017. The studies included observational studies, intervention studies, and studies investigating EED biomarkers and EED diagnosis. These studies were of several EED biomarkers, organized into 5 distinct domains (i.e. 1) intestinal damage and repair; 2) permeability and absorption; 3) microbial translocation; 4) intestinal inflammation and 5) systemic inflammation), that have been used to measure EED, and looked at the relationships within/between the domains (table 1) and then each domain and stunting (table 2). The review yielded (see tables 1 and 2) little evidence to support the pathway from intestinal permeability to microbial translocation and from microbial translocation to stunting. However, there were stronger evident linkages between intestinal inflammation and systemic inflammation and between intestinal inflammation and stunting. Much of the relationships presented conflicting evidence, with even splits across studies. Therefore, results show that the relationships between EED domains are inconsistent and the associations between EED and stunting are variable. Additionally, some domains are harder to measure than others, and the definition of EED is inconsistent across studies, which may have led to a bias in the study findings. Moreover, as EED is histopathological, characterized by small bowel morphological changes, the studies captured in this review are lacking, and more studies are needed to investigate associations between biopsy samples and a range of non-invasive biomarkers from each domain. The review also postulated that the inconsistencies highlighted may indicate that EED may be more complex than previously conceived, and that EED may not be a single entity but rather a set of phenotypes dependent on unique environmental exposures that vary geographically, and that some of the elements of EED may even be adaptive, rather than pathologic for children living in poor WASH conditions.

Humphrey, J. H. (2009). Child undernutrition, tropical enteropathy, toilets, and handwashing. *The Lancet*, 374(9694), 19-25.

Link: [https://doi.org/10.1016/S0140-6736\(09\)60950-8](https://doi.org/10.1016/S0140-6736(09)60950-8)

In this paper, the author hypothesizes that prevention of EED, which afflicts almost all children in the developing world, will be crucial to normalize child growth, and that toilet provision is necessary. Given the Lancet Maternal and Child Undernutrition Series estimated that sanitation and hygiene interventions implemented with 99% coverage would reduce diarrhea incidence by 30%, and decrease the prevalence of stunting by only 2.4%, the author suggests that EED may be more important to consider (and that the Lancet Maternal and Child Undernutrition Series may be underestimating the contribution of sanitation and hygiene to growth. EED (characterized by villous atrophy, crypt hyperplasia, increased permeability, inflammatory cell infiltrate, and modest malabsorption) is caused by fecal bacteria ingested in large quantities by young children living in conditions of poor sanitation and hygiene, and that EED is a causal pathway to undernutrition, not diarrhea. Furthermore, the author urges for more research and RCTs of toilet provision and handwashing promotion that include EED and child growth as outcomes will give valuable evidence and offer a solution to the intractable problem of child undernutrition.

Keusch, G. T., Rosenberg, I. H., Denno, D. M., Duggan, C., Guerrant, R.L., Lavery, J. V., et al. (2013). Implications of acquired environmental enteric dysfunction for growth and stunting in infants and children living in low- and middle-income countries. *Food Nutr Bull.* 2013;34(3):357-64.

Link: <https://doi.org/10.1177/2F156482651303400308>

This report focuses on the implications and resources needed to mobilize investments toward established criteria to assess EED and determine its predictive value for growth faltering, and stunting. It is necessary to identify the causes of EED in order to propose and test potential interventions that move the populations in low-income countries along a pathway for better health for infants and children. This study identified concepts and tools available currently to assess these issues surrounding EED and growth. These include nutrient malabsorption tests (i.e.D-Xylose), intestinal permeability (lactulose and mannitol or rhamnose (L:M or L:R ratio)) which reflect the gut barrier function and intestinal absorptive capacity. In addition, serial intestinal biopsy is also presented as a method to identify EED (the functional and structural changes seen in the gut), but may lead to ethical considerations when considering infants and healthy children. Ultimately, more data is needed to identify which type of test for EED is the most sensitive and specific. The authors suggest a combination of tests, sampled from blood, breath and urine, which assess intestinal absorption and permeability, enterocyte mass, inflammation, and microbial translocation and immune activation. In addition, to understand the extent of stunting related to EED, measures of growth velocity and growth faltering are likely to be early indicators of adverse nutritional consequences of environmental enteric dysfunction when assessed among individuals in longitudinal cohorts.

Ordiz MI, Shaikh N, Trehan I, Maleta K, Stauber J, Shulman R, et al. (2016). Environmental Enteric Dysfunction Is Associated with Poor Linear Growth and Can Be Identified by Host Fecal mRNAs. *J Pediatr Gastroenterol Nutr.* 2016;63(5):453-9.

Link: <https://dx.doi.org/10.1097/2FMPG.0000000000001315>

This was an observational study to determine whether a single L:M predicts subsequent EED and linear growth in these rural Malawian African children. The study identified dietary, demographic, and household sanitation practices that are associated with L:M, and the extent to which fecal host mRNAs predict L:M. The study participants were 798 asymptomatic Malawian children, from 3 clinical studies, aged 12 to 61 months. Each child was compared with linear growth over the subsequent 3 months. Using data from these 3 studies, the primary outcomes evaluated were the ability of L:M to predict

subsequent linear growth in a linear regression model, identification of clinical and environmental risk factors for EED as defined by an abnormal L:M, and the sensitivity and specificity of random forest modeling (computer-generated decision trees from a set independent variables, in our case the copy numbers of a set host transcripts, to designate the child into an EED category) of sets of fecal host transcripts to predict the severity of EED (no, moderate and severe). Results of the study indicated that of the 798 children included in the study, 140 (18%), 524 (66%), and 134 (17%) had no, moderate, or severe EED, respectively. L:M was inversely correlated with linear growth over the subsequent 3 months ($r = -0.32$, $P < 0.001$) and severe EED was associated with stunting ($P < 0.0001$). Age younger than 24 months, weight-for-height z score < 0 , domesticated animals in the child's sleep environment, lack of a pit latrine combined with a potentially contaminated water source, and a recent history of diarrhea were associated with severe EED. A random forest model using CD53, HLA-DRA, MUC12, and TNF was 84% sensitive for severe EED and 83% sensitive for no EED.

Owino, V., Ahmed, T., Freemark, M., Kelly, P., Loy, A., Manary, M., et al. (2016). Environmental Enteric Dysfunction and Growth Failure/Stunting in Global Child Health. *Pediatrics*. 2016;138(6).

Link: <https://doi.org/10.1542/peds.2016-0641>

With stunting pathogenesis poorly understood, further study of EED and its implicate, central role in the disturbance of small intestinal structure and function and link to stunting is warranted. Mechanisms contributing to growth failure in EED include intestinal leakiness and heightened permeability, gut inflammation, dysbiosis and bacterial translocation, systemic inflammation, and nutrient malabsorption. With EED's causal pathways being complex and diverse, approaches to manage the infection will need to be multifaceted. Interventions include:

1. Reduction of exposure to feces and contact with animals through programs such as improved water, sanitation, and hygiene
2. Breastfeeding and enhanced dietary diversity
3. Probiotics and prebiotics
4. Nutrient supplements, including zinc, polyunsaturated fatty acids, and amino acids
5. Anti-inflammatory agents such as 5-aminosalicylic acid
6. Antibiotics in the context of acute malnutrition and infection.

The authors of this study point to new development of noninvasive, practical, simple, and affordable point-of-care diagnostic tools remain key gaps for identifying EED. Genomics, epigenomics, transcriptomics, proteomics, and metabolomics, as well as stable isotope techniques (e.g., ^{13}C breath tests) targeted at children and their intestinal microbiota will enhance our ability to successfully identify, manage, and prevent EED.

Penakalapati, G., Swarthout, J., Delahoy, M. J., McAliley, L., Wodnik, B., Levy, K., and Freeman, M. C. (2017). Exposure to Animal Feces and Human Health: A Systematic Review and Proposed Research Priorities. *Environmental Science and Technology*, 51(20), 11537–11552.

Link: <https://doi.org/10.1021/acs.est.7b02811>

This systematic review of both peer-reviewed and gray literature examined the human health impacts of exposure to poorly managed animal feces transmitted via water, sanitation, and hygiene (WASH)-related pathways in low- and middle-income countries, where household livestock, small-scale animal operations, and free-roaming animals are common. Authors identify routes of contamination by animal feces, control measures to reduce human exposure, and propose research priorities for further inquiry. Exposure to animal feces has been associated with diarrhea, soil-transmitted helminthes (STH) infection, trachoma, EED, and stunting. Few studies have evaluated control measures, but interventions include reducing cohabitation with animals, provision of animal feces scoops, controlling animal movement, creating safe child spaces, improving veterinary care, and hygiene promotion.

Future research should evaluate: behaviors related to points of contact with animal feces; animal fecal contamination of food; cultural behaviors of animal fecal management/animal husbandry practices; acute and chronic health risks associated with exposure to animal feces; and factors influencing concentrations and shedding rates of pathogens originating from animal feces.

Prendergast, A. J., Humphrey, J. H., Mutasa, K., Majo, F. D., Rukobo, S., Govha, M., ... and Stoltzfus, R. J. (2015). Assessment of environmental enteric dysfunction in the SHINE trial: methods and challenges. *Clinical Infectious Diseases*, 61(suppl 7), S726-S732.
Link: <https://doi.org/10.1093/cid/civ848>

The Sanitation Hygiene Infant Nutrition Efficacy (SHINE) trial in Zimbabwe is evaluating the independent and combined effects of a package of infant feeding and/or water, sanitation, and hygiene interventions on stunting and anemia. The SHINE trial longitudinally evaluates EED in a well-characterized cohort of infants, using a panel of biomarkers along the hypothesized causal pathway. Using sampled stool, blood and urine, the biomarkers include: intestinal absorption (mannitol recovery), intestinal inflammation (alpha 1 antitrypsin, neopterin, myeloperoxidase), enterocyte damage (I-FABP), intestinal regeneration (REG-1B), intestinal barrier (lactulose recovery), microbial translocation (EndoCAB, LPS^b, sCD14, sCD163), systemic inflammation (CRP, AGP), and growth hormone activity (IGF-1). The specific aims of the SHINE trial are to describe the evolution of EED during infancy, ascertain its contribution to stunting, and investigate the impact of the randomized interventions on the EED pathway. The conclusions of this article are:

- EED is a nearly ubiquitous, but is a very poorly defined disorder of the small intestine of people living in poor WASH conditions (poverty) that begins early in infancy and persists.
- It can impact linear growth, neurodevelopment, oral vaccine responses, and immune ontogeny.
- With trials underway to assess interventions, several research groups are actively evaluating novel markers of EED, but currently there is no accepted case definition or gold-standard biomarker, making field studies challenging.

Smith LE, Prendergast AJ, Turner PC, Mbuya MN, Mutasa K, Kembo G, et al. (2015). The Potential Role of Mycotoxins as a Contributor to Stunting in the SHINE Trial. *Clin Infect Dis*. 2015;61 Suppl 7:S733-7.

Link: <https://doi.org/10.1093/cid/civ849>

Children in developing countries experience multiple exposures that are harmful to their growth and development. Mycotoxins are an emerging concern since they contaminate a wide range of cereals and staple foods consumed in developing countries, and contribute to poor child health and development. Three mycotoxins are of major concern to child health and development. These include: aflatoxin, fumonisin, and deoxynivalenol. As illustrated by the SHINE trial, the authors summarize the evidence that mycotoxin exposure is associated with stunting, proposed through both EED and the disturbance of the insulin-like growth factor 1 (IGF-1) axis. The four objectives of this sub-study in rural Zimbabwe (part of the SHINE trial) are to:

1. assess the relationship between Pre- and postharvest crop management of agricultural and harvest practices and mycotoxin exposure (association between mycotoxin risk and household characteristics, geographic locale, season, year, and rainfall. In addition, mycotoxin risk and associated biomarkers in infants and mothers)
2. to evaluate associations between mycotoxin exposure and child stunting (by age and season)
3. to investigate EED as a potential pathway linking mycotoxin exposure to child stunting
4. to inform potential areas for intervention to reduce mycotoxin exposure

Trehan I, Kelly P, Shaikh N, Manary MJ. (2016) New insights into environmental enteric dysfunction. *Arch Dis Child*. 2016;101(8):741-4.

Link: <http://dx.doi.org/10.1136/archdischild-2015-309534>

EED has been recognized as an important contributing factor to physical and cognitive stunting, poor response to oral vaccines, limited resilience to acute infections and ultimately global childhood mortality. This paper reviews a series of trials designed to decrease EED and stunting that take on novel approaches, including improvements in sanitation, hygiene and nutritional interventions. These include:

- Assessment of the human host transcriptome in stool samples: revealed a panel of 51 transcripts significantly associated with stunting and EED.
- Metabolome studies: identifying serum markers of gut inflammation and breakdown. There may be positive or negative alterations in essential metabolites involved in gut function and integrity, nutrient absorption, energy metabolism and those involved in growth and differentiation.
- Anti-inflammatory medications: mesalazine shows some promise.
- Improving WASH: epidemiological link between EED and poor sanitation, exposure to animal feces, lack of access to soap and water for hand and face washing, and consumption of contaminated food and water. Poor sanitation facilitates may be a constant exposure to microbes in the small intestine, provoking the chronic inflammatory state and defective integrity of the gut observed in EED. Two very large multicenter clinical studies, water, sanitation and hygiene (WASH) Benefits and the Sanitation Hygiene Infant Nutrition Efficacy (SHINE) Trial should provide ample opportunities to better understand EED and stunting over the next several years as results become available.
- Nutritional interventions: investigations of the natural anti-inflammatory and microbiome-modifying properties of specific nutrients and foods. Supplementary/weaning food trials using specific amino acids (i.e. arginine and glutamine), proteins (i.e. lactoferrin and lysozyme), and legumes have potential for demonstrating improvements in EED and subsequent stunting. Investigating foods, either GMO or natural, which are high in growth factors that may reduce apoptosis, enhance enterocyte proliferation, and/or stimulate villous growth should be promising.

Harper, K. M., Mutasa, M., Prendergast, A. J., Humphrey, J., and Manges, A. R. (2018). Environmental enteric dysfunction pathways and child stunting: A systematic review. *PLOS Neglected Tropical Diseases*, 12(1).

Link: <https://doi.org/10.1371/journal.pntd.0006205>

EED is commonly defined as “an acquired subclinical disorder of the small intestine characterized by villous atrophy and crypt hyperplasia,” and it is proposed to underlie stunted growth among children in developing countries. This study is a systematic literature review looking at studies from 2010-2017. The studies included observational studies, intervention studies, and studies investigating EED biomarkers and EED diagnosis. These studies were of several EED biomarkers, organized into 5 distinct domains (i.e. 1) intestinal damage and repair; 2) permeability and absorption; 3) microbial translocation; 4) intestinal inflammation and 5) systemic inflammation), that have been used to measure EED, and looked at the relationships within/between the domains (table 1) and then each domain and stunting (table 2). The review yielded (see tables 1 and 2) little evidence to support the pathway from intestinal permeability to microbial translocation and from microbial translocation to stunting. However, there were stronger evident linkages between intestinal inflammation and systemic inflammation and between intestinal inflammation and stunting. Much of the relationships presented conflicting evidence, with even splits across studies. Therefore, results show that the relationships between EED domains are inconsistent and the associations between EED and stunting are variable. Additionally, some domains are harder to measure than others, and the definition of EED is inconsistent across studies, which may have led to a bias in the study findings. Moreover, as EED is histopathological, characterized by small bowel morphological changes, the studies captured in this review are lacking, and more studies are needed to investigate associations between biopsy samples and a range of non-invasive biomarkers from each domain. The review also postulated that the

inconsistencies highlighted may indicate that EED may be more complex than previously conceived, and that EED may not be a single entity but rather a set of phenotypes dependent on unique environmental exposures that vary geographically, and that some of the elements of EED may even be adaptive, rather than pathologic for children living in poor WASH conditions.

Penakalapati, G., Swarthout, J., Delahoy, M. J., McAliley, L., Wodnik, B., Levy, K., and Freeman, M. C. (2017). Exposure to Animal Feces and Human Health: A Systematic Review and Proposed Research Priorities. *Environmental Science and Technology*, 51(20), 11537–11552.
Link: <https://doi.org/10.1021/acs.est.7b02811>

This systematic review of both peer-reviewed and gray literature examined the human health impacts of exposure to poorly managed animal feces transmitted via water, sanitation, and hygiene (WASH)-related pathways in low- and middle-income countries, where household livestock, small-scale animal operations, and free-roaming animals are common. Authors identify routes of contamination by animal feces, control measures to reduce human exposure, and propose research priorities for further inquiry. Exposure to animal feces has been associated with diarrhea, soil-transmitted helminthes (STH) infection, trachoma, EED, and stunting. Few studies have evaluated control measures, but interventions include reducing cohabitation with animals, provision of animal feces scoops, controlling animal movement, creating safe child spaces, improving veterinary care, and hygiene promotion. Future research should evaluate: behaviors related to points of contact with animal feces; animal fecal contamination of food; cultural behaviors of animal fecal management/animal husbandry practices; acute and chronic health risks associated with exposure to animal feces; and factors influencing concentrations and shedding rates of pathogens originating from animal feces.

Velly, H., Britton, R. A., and Preidis, G. A. (2017). Mechanisms of cross-talk between the diet, the intestinal microbiome, and the undernourished host. *Gut Microbes*.
Link: <https://doi.org/10.1080/19490976.2016.1267888>

This research highlights the evidence that unhealthy gut microbial populations (intestinal microbial dysbiosis) perpetuate the vicious cycle of pathophysiology that results in persistent growth impairment in children, in addition to nutritional inputs, and EED (the collective of inflammation, barrier dysfunction, predilection to pathogen invasion, altered transit, and malabsorption). Metagenomics has indicated several mechanisms by which these alterations may affect growth. The authors summarize a variety of observational studies that highlight:

1. Differences in the composition and function of gut microbiota between undernourished and healthy children (where they uncovered that undernourished children have: a) distinct patterns of gut bacterial community configurations, b) delayed gut microbiota maturity).
2. Discussions on dietary, environmental (i.e. children of diverse genetic backgrounds who live in poor WASH conditions and among many enteropathogens), and host factors (i.e. children of diverse genetic backgrounds and susceptibility) that shape this altered microbiome in undernourished children.
3. The consequences of these changes on the host physiology (i.e. loss of microbial diversity observed in undernourished children. This could place these children at higher risk of more frequent and more severe entero-pathogen infections, perpetuating the vicious cycle of EED, inflammation, and impaired growth. Dysbiosis can impact dietary energy harvest affecting host metabolism, de novo micronutrient synthesis/amino acid and vitamin-metabolism pathways, and bile acid homeostasis/regulation. These can affect energy metabolism, absorption of dietary fat-soluble vitamins and weight gain in undernourished children. In addition, transplants of human-derived microbes into gnotobiotic mice provide evidence of a causal link between dysbiosis, discordant weight loss and growth impairment, etc.

4. The considerations of the opportunities for microbiome-targeting therapies to alleviate undernutrition. These include: antibiotics, probiotics, low cost diagnostics, and prebiotics.

Wang, A.Z., Shulman, R.J., Crocker, A.H., Thakwalakwa, C., Maleta, K.M., Devaraj, S., et al. (2017). A Combined Intervention of Zinc, Multiple Micronutrients, and Albendazole Does Not Ameliorate Environmental Enteric Dysfunction or Stunting in Rural Malawian Children in a Double-Blind Randomized Controlled Trial. *Journal of Nutrition*. 2017;147(1):97-103.
Link: <https://doi.org/10.3945/jn.116.237735>

As a result of previous research demonstrating 3 interventions (that are safe, have few side effects and are readily available in the developing world), individually, led to improvements in the L:M ratio compared to placebo, the authors of this study hypothesized that combining these 3 would ameliorate EED more efficaciously. The three interventions included zinc, albendazole, and micronutrient supplementation. This hypothesis was tested over 12-24 wk in a randomized, double-blind, placebo-controlled clinical trial cohort of rural Malawian children 12-35 mo old. The primary outcomes were improvements in EED, as measured by the urinary lactulose-to-mannitol ratio (L:M ratio) from dual-sugar absorption testing, and linear growth. Urinary L:M ratios and anthropometric measurements were evaluated after 12 and 24 wk of intervention and compared with a placebo (no intervention). Ultimately the results of the study indicated no improvement in EED with respect to all three interventions administered in unison. After 12 and 24 wk of study, increases in the L:M ratio did not differ between the intervention group (0.071 for L and 0.088 units for M) and the placebo group (0.073 for L 0.080 units for M) (with a p-value = 0.87 for L and 0.19 for M). In addition, relative changes in length and weight did not differ significantly between the groups at any time point during the study.

Yu, J., Ordiz, M.I., Stauber, J., Shaikh, N., Trehan, I., Barnell, E., et al. (2016) Environmental Enteric Dysfunction Includes a Broad Spectrum of Inflammatory Responses and Epithelial Repair Processes. *Cell Mol Gastroenterol Hepatol*. 2016;2(2):158-74 e1.
Link: <https://doi.org/10.1016/j.jcmgh.2015.12.002>

This study elucidated how differentially expressed transcripts, appropriately enumerated, may be explored as potential biomarkers for EED. In this paper, the host transcriptome in feces was characterized, using a novel microarray method to overcome limitation of RNA sequencing, in a prospective cohort observational study of 259 rural Malawian children (age 12-61 months) at risk for EED, which was measured by lactulose permeability (%L). The primary outcomes were the correlation between %L and expression levels of protein coding genes, based on data that %L correlates with linear growth in this population. Secondary outcomes were with transcripts that were correlated significantly with %L associated with canonical pathways in EED (Transcripts that were associated with %L also were tested for association with change in HAZ, linear growth indicator). Overall, 12 transcripts associated with the severity of EED. In addition, a broad range of immune activation and defects in cell adhesion were found, coupled with decreased mucin (associated with the maintenance of the mucous layer) elucidating the pathobiology of EED.

Additional Resources:

- Brown G, Hoehn N, Decaro J, Piperata B, Schmeer K, Wilson W. Linking growth and gut function: Environmental enteropathy in children under 2 years in rural Nicaragua. *American Journal of Human Biology*. 2017;29(2).
- Faubion, W.A., Camilleri, M., Murray, J.A., Kelly, P., Amadi, B., Kosek, M. N., . . . Singh, R. (2016) Improving the detection of environmental enteric dysfunction: a lactulose, rhamnose assay of intestinal permeability in children aged under 5 years exposed to poor sanitation and hygiene. *BMJ Global Health*, 1, 1-8.

- Goodgame RW. (1996) Understanding intestinal spore-forming protozoa: Cryptosporidia, Microsporidia, Isospora, and Cyclospora. *Annals of Internal Medicine*. 1996;124(4):429-41.
- Gordon, J. I., Dewey, K. G., Mills, D. A., and Medzhitov, R. M. (2012). The human gut microbiota and undernutrition. *Science translational medicine*, 4(137), 137ps12-137ps12.
- Korpe PS, Petri WA, Jr. (2012). Environmental enteropathy: critical implications of a poorly understood condition. *Trends Mol Med*. 2012;18(6):328-36.
- Salazar-Lindo E, Allen S, Brewster DR, Elliott EJ, Fasano A, Phillips AD, et al. (2004). Intestinal infections and environmental enteropathy: Working Group report of the second World Congress of Pediatric Gastroenterology, Hepatology, and Nutrition. *J Pediatr Gastroenterol Nutr*. 2004;39 Suppl 2:S662-9.
- Weisz AJ, Manary MJ, Stephenson K, Agapova S, Manary FG, Thakwalakwa C, et al. (2012) Abnormal gut integrity is associated with reduced linear growth in rural Malawian children. *J Pediatr Gastroenterol Nutr*. 2012;55(6):747-50.

Mycotoxins

- Wu, F. (2017, March). **Mycotoxins in animal feed: Risks to animal and human health.** *Nurturing development: Improving human nutrition with animal-source foods*. Video. Symposium conducted at the University of Florida, Gainesville, FL.
Link: [Wu](#)

The author introduces the four major classes of mycotoxins found: aflatoxins, fumonisins, ochratoxins, and deoxynivalenol. In the United States, there have been aflatoxin levels set for different animals. Mycotoxins have an economic impact as detectable levels result in loss of productivity. In the rest of the world, mycotoxins may not be monitored as closely and can present issues on animal and human health. Mycotoxins reduce the efficiency of animal feed resulting in a reduction in animal growth; these toxins also cause gastrointestinal dysfunctions in animals. Factors that influence mycotoxins include climate, other environmental factors, and livestock grower practices. The author indicates interventions at the pre- and post-harvest stage could reduce risk. One way to overcome the risk of mycotoxins include diet diversity to reduce the impact.

Soil as a Pathway to EED

- George, C. M., Oldja, L. Biswas, S., Perin, J., Lee, G. O., Kosek, M. Sack, R. B., . . . Faruque, A. G. (2015). Geophagy is associated with environmental enteropathy and stunting in children in rural Bangladesh. *The American Journal of Tropical Medicine and Hygiene*, 92(6), 117-1124.
Link: <https://doi.org/10.4269/ajtmh.14-0672>

The article discusses the lack of study surrounding geophagy events as an influencer for environmental enteropathy. The authors argue that although research has been done to indicate soil as an exposure route for enteric pathogens and the fecal-oral route of transmission of enteric infections through the F diagram (fluids, fingers, fields, flies, and flood), few studies have researched geophagy as influencing environmental enteropathy (EE) or measures of growth. The researchers conducted a prospective cohort study of 216 children (under the age of 5) in rural Bangladesh to identify geophagy events, which were determined by using a 5-hour observation of a child's behaviors in conjunction with report answers on geophagy events given by caretakers. These results were then used to determine relationships to an EE disease activity score (from stool samples) and measures of stunting. Significant results of the study included the findings that all study households had visible feces present in outdoor areas where children played, and that 97% of fecal samples had detectable *E. coli*, of which 14% were

the diarrheagenic form. Other findings included that one-third of children were reported as having consumed soil in the past week. It was also found that caregivers did little to prevent the children from consuming soil. Children were observed to have geophagy events at 18% in the past week, with 28% were reported by their caregiver(s) as having events in the past week. Findings showed a significant association was between caregiver-reported geophagy events and EE disease activity scores, as well as with increased EE scores and being underweight. Though the researchers did find the odds for stunting increased in children whose caregivers reported having geophagy events, a significant association between only the observations of geophagy events and EE markers, or stunting, was not found. Researchers hypothesize the lack of significant association to be driven by the reporting bias created by the short time-frame of observation.

Shivoga, W. A., and Moturi, W. N. (2009). Geophagia as a risk factor for diarrhea. *The Journal of Infection in Developing Countries*, 3(2), 94-98.

Link: <https://doi.org/10.3855/jidc.55>

The aim for this longitudinal study was to determine whether children, under the age of 5, who ingested soil had a higher prevalence of diarrhea within a sample size of 350 households throughout Kenya. The study was conducted between April and October of 2005, and 175 households were randomly selected in each of the two locations—Mauche and Nessuit. The researchers administered questionnaires to the caretaker of the household to identify whether a child ate soil and how much, and prevalence of diarrhea in children was reported by the questionnaire taker. Observed the layout of the home and reported on the hygienic facilities available. These findings led researchers to hypothesize that the present feces were the causes of the bacteria in the soil, and the cause of the diarrhea. Percentages of households were found to have respective fecal contamination levels—human feces (47%) and animal feces (74%). In children who ingested soil ‘occasionally’ or ‘a lot’, the most common type of latrine was a simple pit with a wood floor, or no latrine. Statistical analysis findings showed that (at a 0.01 confidence level) diarrhea was found to have a positive correlation with earth eating ($r=0.306$), the presence of human feces in the yard ($r=0.587$), animal feces in the yard ($r=0.225$), and the child not wearing a loincloth ($r=0.471$). At the same confidence level, there was a positive correlation between a child not wearing a loincloth, and human feces being present in the yard ($r=0.599$). Additionally, at the confidence level of 0.05, a positive correlation was found with no latrine in the homestead and human feces in the yard ($r=0.185$). The latter finding was thought to be because a lack of loincloth meant the child could defecate anywhere in the yard with more ease.

Additional Resources:

Geissler, P. W., Mwaniki, D., Thiong'o, F., and Friis, Henrik. (1998). Geophagy as a risk factor for geohelminth infections: A longitudinal study of Kenyan primary schoolchildren. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, 92(1), 7-11.

Kumar, S. G., and Subita, L. (2013). Diarrhoeal diseases in developing countries: a situational analysis. *Kathmandu University Medical Journal*, 10(2), 83-88.

Other Risks

Chen, C., Mitchell, N. J., Gratz, J., Houpt, E. R., Gong, Y., Egner, P. A., and Mduma, E. R. (2018). Exposure to aflatoxin and fumonisin in children at risk for growth impairment in rural Tanzania. *Environment international*, 115, 29-37.

Link: <https://doi.org/10.1016/j.envint.2018.03.001>

Studies in the past attempting to reduce the prevalence of child stunting and growth impairment in Africa have focused mainly on fixing micronutrient deficiencies or providing vaccinations, yet most have provided underwhelming results even after implementation of treatment plans, suggesting the presence of more undefined underlying risk factors. Because of the significant consumption of maize and cereal grains in these low-income countries, the purpose of this study was to analyze the potential role of two dietary mycotoxins, aflatoxin and fumonisin, on growth impairment of children in Tanzania. Both of these toxins are known to commonly infect major food crops often grown in warm climates, especially maize. A total of 114 children from Haydom, Tanzania were recruited for the study, and appropriate markers of aflatoxin and fumonisin exposure were collected at 24 months and between 24 and 36 months, respectively. AFB1-lys, an indicator in plasma of long-term dietary exposure over the past few months, was used to quantify aflatoxin exposure, and urinary fumonisin B1 (UFB1), a useful biomarker in urine indicating dietary exposure over the past 24 hours, was used to quantify fumonisin exposure. Statistical analysis of the data revealed no correlations between AFB1-lys and growth impairment as measured by the children's height and weight Z-score values. This could be attributed to the presence of a threshold of aflatoxin intake, or a level below which aflatoxin exposure would have no effect on a child's growth. As they continue to grow and consume higher amounts of maize and maize-based products throughout their lives, their exposure to aflatoxin levels may reach this point to where it could have an impact on their further growth and development. As for fumonisin exposure, regression analysis of UFB1 revealed a significant negative correlation with the children's weight-for-age Z-scores, suggesting dietary intake of fumonisin as a factor of growth impairment of children in Tanzania. Comparison of fumonisin concentrations in the children also revealed the possibility of a dose-dependent effect, similar to the threshold defined above for aflatoxin, where greater exposure above a certain level would have a greater impact on stunting and growth impairment.

Rogers, L. M., Boy, E., Miller, J. W., Green, R., Rodriguez, M., Chew, F., and Allen, L. H. (2003). Predictors of cobalamin deficiency in Guatemalan school children: diet, *Helicobacter pylori*, or bacterial overgrowth? *Journal of pediatric gastroenterology and nutrition*, 36(1), 27-36.
Link: <https://doi.org/10.1097/00005176-200301000-00008>

Cobalamin deficiencies have been found to be highly prevalent within developing countries, yet the major cause behind this has yet to be discovered. The purpose of this study was to analyze the potential relationships between low dietary vitamin B12 intake, impaired gastric function, bacterial overgrowth, and *Helicobacter pylori* infection with cobalamin (vitamin B12) deficiency often found in Guatemalan children. To study the association between each factor and the cobalamin deficiency, sixty children with low plasma cobalamin concentrations (<162 pmol/L) were matched to sixty children with marginal plasma concentrations (162-221 pmol/L) and sixty children with adequate plasma concentrations (>221 pmol/L). Children from ages eight to twelve were selected from three schools in a low-income area of Guatemala City. Out of all the possible factors examined in this study, the only one that proved to be a significant predictor of plasma cobalamin concentration was dietary intake of vitamin B12. Both bacterial growth and *Helicobacter pylori* were not able to predict plasma cobalamin concentration values, which suggested that both of these factors have no effect on the absorption of this vitamin within this specific population. Overall, the study results suggested that the lack of vitamin B12 intake in their diets was contributing to the prevalent cobalamin deficiencies seen within the local population.

World Health Organization. (2015). WHO estimates of the global burden of foodborne diseases: foodborne disease burden epidemiology reference group 2007-2015.
Link: http://apps.who.int/iris/bitstream/10665/199350/1/9789241565165_eng.pdf

This report set out to estimate the incidence, mortality, economic impact, and overall burden of foodborne diseases worldwide. Information on foodborne diseases of microbial, chemical, and parasitic origin can be found in the report according to characteristics such as region, age, and gender. However, the information included is intended to provide a lasting impression on a regional and local scale, rather than just a list of global estimates. Foodborne disease often goes unacknowledged within low-income and developing nations, yet these are the places where recognition of this ongoing problem could have the biggest impact. The burden in these areas is considerably worse, particularly in the children under the age of five. Because of this, the ultimate goal of this initiative by the World Health Organization is to empower local policy-makers across the globe to create sustainable and meaningful change through evidence-based decisions about foodborne disease within their regions.

Excreta and sludge as risk factor

Strauch, D. (1991). Survival of pathogenic micro-organisms and parasites in excreta, manure and sewage sludge. *Revue Scientifique et Technique (International Office of Epizootics)*, 10(3), 813–846.

Link: <http://dx.doi.org/10.20506/rst.10.3.565>

This article investigated pathogens survival in excreta, manure, and sewage in the various epidemiological aspects of agricultural sludge utilization. The authors illustrate how livestock housing can introduce pathogens, and aid their survival when they reach the floor installations, collected as a solid or liquid. In these cases, the manure may contain pathogens, and many owners neglect this in their management practice. To protect the livestock of the farms utilizing sewage sludge as fertilizer or for amending soils it is necessary to sanitize sludge prior to use (Strauch, 1991).

WASH as a Factor of EED

Langford, R., and Lunn, P. (2011). Hand-washing, subclinical infections, and growth: A longitudinal evaluation of an intervention in Nepali slums. *American Journal of Human Biology*, 23(5), 621-629.

Link: <https://doi.org/10.1002/ajhb.21189>

The authors conducted a longitudinal study, which assessed the impacts hand-washing interventions have on the growth and biomarkers of childhood health in Nepali slums. The article presents the importance of diarrhea as a symptom of subclinical infection. The article discusses how, due to poor environmental conditions in the developing world, children may be frequently exposed to pathogens and have high instances of recurring subclinical infections. The study hypothesis was that better hand hygiene would reduce clinical morbidity, mucosal damage, and markers of immune stimulation and growth faltering in children—of which diarrhea can be a symptom. Researchers conducted structured observations and questionnaires of 75 households which were utilized to determine hygiene behaviors. Findings for the intervention group found that more frequent hand washing and resulted in fewer diarrheal episodes; however, no impact was found on levels of mucosal damage and immune stimulation that have an association child growth. The authors conclude that hand-washing interventions may have little to no effect on sub-clinical infections in relation to childhood growth.

Lin, A., Arnold, B. F., Afreen, S., Goto, R., Huda, T. M. N., Haque, R., Raqib, R., ... Luby, S. P. (2013). Household environmental conditions are associated with enteropathy and impaired growth in rural Bangladesh. *The American Society of Tropical Medicine and Hygiene*, 89(1), 130-137.

Link: <https://doi.org/10.4269/ajtmh.12-0629>

This study was an analytical cohort study, serving as a follow-up to evaluate previously implemented interventions by the Bangladesh Department of Public Health Engineering, United Nations Children's Fund (UNICEF), and the Department for International Development of the British Government. The intervention previously put in place was through the campaign called, the Sanitation, Hygiene Education, and Water Supply-Bangladesh (SHEWA-B). The authors of this study hypothesized that children living in households with good hygiene systems, who received earlier interventions, would exhibit lower prevalence rates of parasites and EE and better growth than children who lived in households with poor hygiene systems without interventions. The researchers compared households with good hygiene systems to those with poor systems. A total of 119 children were studied from rural Bangladesh communities. Household water, sanitation, and hygiene conditions were surveyed to determine conditions. Stool samples of children were collected and tested for *Cryptosporidium parvum*, *Giardia lamblia*, *Entamoeba histolytica*, *Ascaris lumbricoides*, *Trichuris trichiura*, and hookworm. Urine samples were collected and tested for LM concentrations. Blood samples were taken to examine IgG and EndoCAb levels. Anthropometric measures were also taken. Findings concluded that children from households with good hygiene systems had lower presence of parasitic infections, better gut function, and superior growth when compared to those from households with poor hygiene systems.

Luby, S. P., Rahman, M., Arnold, B. F., Unicomb, L., Ashraf, S., Winch, P. J., ... and Colford, J. M. (2018). Effects of water quality, sanitation, handwashing, and nutritional interventions on diarrhoea and child growth in rural Bangladesh: A cluster randomised controlled trial. *The Lancet Global Health*.

Link: [https://doi.org/10.1016/S2214-109X\(17\)30490-4](https://doi.org/10.1016/S2214-109X(17)30490-4)

The WASH Benefits Bangladesh cluster-randomized trial enrolled pregnant women from villages in rural Bangladesh and evaluated outcomes at 1-year and 2-years' follow-up. The aim of this study was to assess whether WASH interventions, alone, or combined with nutrition interventions reduced diarrhea or growth faltering/stunting. The authors assessed that nutrient supplementation and counseling modestly improved linear growth, but there was no benefit to the integration of WASH with nutrition. Adherence was high in all groups and diarrhea prevalence was reduced in all intervention groups except water treatment. Combined water, sanitation, and handwashing interventions were not consistently effective in prevention of diarrhea and provided no additive benefit over single interventions. These findings suggest that focusing resources on a single low-cost, high-uptake intervention to a larger population might reduce diarrhea prevalence more than would similar spending on more comprehensive approaches to smaller populations.

Additional Resources:

Bennett, D., Naqvi, S. A. A., and Schmidt, W. P. (2014). *Learning, hygiene, and traditional medicine* (No. 14/25). HEDG, c/o Department of Economics, University of York.

Dearden, K. A., Schott, W., Crookston, B. T., Humphries, D. L., Penny, M. E., and Behrman, J. R. (2017). Children with access to improved sanitation but not improved water are at lower risk of stunting compared to children without access: a cohort study in Ethiopia, India, Peru, and Vietnam. *BMC public health*, 17(1), 110.

Mara D. The elimination of open defecation and its adverse health effects: a moral imperative for governments and development professionals. *Journal of Water Sanitation and Hygiene for Development*. 2017;7(1):1-12.

Reese H, Routray P, Torondel B, Sclar G, Delea MG, Sinharoy SS, et al. (2017). Design and rationale of a matched cohort study to assess the effectiveness of a combined household-level piped water and sanitation intervention in rural Odisha, India. *Bmj Open*. 2017;7.

Water, Sanitation, and Hygiene Intervention Programs

- Humphrey, J. H., Jones, A. D., Manges, A., Mangwadu, G., Maluccio, J. A., Mbuya, M. N., ... and Tielsch, J. M. (2015). The Sanitation Hygiene Infant Nutrition Efficacy (SHINE) trial: rationale, design, and methods. *Clinical Infectious Diseases*, 61(suppl 7), S685-S702.
Link: <https://doi.org/10.1093/cid/civ844>

This paper is an overview of the SHINE trial, which also includes information on the importance of childhood stunting and anemia in relation to EED, as well as general information on EED. The SHINE trial focused on protecting babies from ingesting fecal matter, and tested such effects independently and combined. This trial was the result of formative research and the incorporation of evidence-based behavior change strategies using education, which resulted in a, “proof of concept, 2 x 2 factorial, cluster-randomized, community-based trial in 2 rural districts of Zimbabwe.” The network of the Zimbabwe Ministry of Health and Child Care’s village health workers (VHWs) was used for cluster development. Clusters were defined using the catchment area of (1-4) community-based VHWs, and were stratified by district. A total of 212 clusters were developed from contiguous districts of Shurugwi and Chirumanzu. These areas were chosen due to being mostly rural, having low sanitation coverage, and a high prevalence of childhood stunting, decent road access, availability of primary healthcare services, geographic location, and stakeholder receptivity. From these 212 catchment areas, a total of 5000 pregnant women, ages 15-49, were enrolled in the surveillance system between November 2012-March 2015. All women received 15 visits from their catchment area’s VHW from their point of enrollment until 18 months postpartum—during which, randomized lessons in standards-of-care (SOC), water, sanitation, and hygiene (WASH), as well as infant and young child feeding (IYCF) were given to the expecting/new mothers. In addition to educational intervention measures for WASH, the construction of a Blair ventilated improved pit (VIP) latrine and 2 “Tippy Tap” handwashing stations early on during gestation and enrollment. Additional home visits were administered by a separate research staff, to help minimize reporting bias, during gestation (approximately 14 and 32 weeks) and postpartum (1, 3, 6, 12, and 18 months), in order to assess the delivery and uptake of intervention lessons. The SHINE trial will be analyzed in a longitudinal observational design, measurements are being gathered, and it is funded by the Bill and Melinda Gates Foundation.

- Mbuya, M. N., and Humphrey, J. H. (2016). Preventing environmental enteric dysfunction through improved water, sanitation and hygiene: An opportunity for stunting reduction in developing countries. *Maternal and Child Nutrition*, 12, 106-120.
Link: <https://doi.org/10.1111/mcn.12220>

This review article serves as an examination of the biological explanation of EED by highlighting the functions of a healthy small intestine, what EED is, and the epidemiology and etiology of the disorder. The authors stressed that, although diarrhea was thought to be strongly associated with linear growth in children, water and sanitation may have stronger influences on these outcomes. The authors argue that enteropathy and immune-stimulation play a role in the stunting; however, a gap in research is creating doubt. The main argument of the article is how prevention of enteric pathogen ingestion by infants and children could prevent EED. Researchers proposed interventions to prevent EED through baby-targeted WASH interventions.

- Null, C., Stewart, C. P., Pickering, A. J., Dentz, H. N., Arnold, B. F., Arnold, C. D., ... and Colford, J. M. (2018). Effects of water quality, sanitation, handwashing, and nutritional interventions on

diarrhoea and child growth in rural Kenya: A cluster-randomised controlled trial. *The Lancet Global Health*.

Link: [https://doi.org/10.1016/S2214-109X\(18\)30005-6](https://doi.org/10.1016/S2214-109X(18)30005-6)

Malnutrition and enteric infection are thought to act together to impair child health and survival as well as growth. This study (trial), WASH benefits, is one of the first cluster-randomized trials to provide experimental evidence on whether individual or combined WASH interventions improve growth; combined WASH interventions are more effective at reducing diarrhea and stunting than an intervention alone; and whether nutrition counseling and supplementation are more effective when combined with improved WASH. The study conducted in rural Kenya, enrolled pregnant women from villages and evaluated outcomes at 1 and 2 years of follow up. The methods included: block-randomization of clusters to (1) active control (household visits to measure mid-upper-arm circumference), (2) passive control (data collection only), or (3) compound-level interventions including household visits to promote target behaviors in WASH and nutrition (i.e. a) drinking chlorinated water (water); b) safe sanitation consisting of disposing feces in an improved latrine (sanitation); c) hand washing with soap (hand washing); d) combined water, sanitation, and hand washing; e) counseling on appropriate maternal, infant, and young child feeding plus small-quantity lipid-based nutrient supplements from 6–24 months (nutrition); and f) combined water, sanitation, hand washing, and nutrition). Primary outcomes were caregiver-reported diarrhea in the past 7 days and length-for-age Z score at year 2 in index children born to the enrolled pregnant women. The trial found that none of the interventions reduced diarrhea, and only the interventions that included nutrition counseling and supplementation improved growth. The authors stipulate that the interventions might have been more efficacious with higher adherence or in an environment with lower baseline sanitation coverage (Null et al., 2018).

Syed, S., Ali, A., and Duggan, C. (2016). Environmental enteric dysfunction in children. *Journal of Pediatric Gastroenterology and Nutrition*, 63(1), 6-14.

Link: <https://dx.doi.org/10.1097%2FMPG.0000000000001147>

This invited review article explains the epidemiology of EED and the pathology of the enterotoxins which cause bodily dysfunction, in relevance to current fieldwork and findings. Since there is no single, or simple set, of biomarkers to identify EED, this article presents the categories of biomarkers to effectively detect bowel dysfunction. Biomarkers utilized include—measurement of gastrointestinal absorption and mucosal permeability characteristics, enterocyte mass and function, inflammation, microbial translocation and immune activation, and intestinal injury and repair. The article mentions the types of interventions studied for treatment of EED, but notes that for effective strategies to be developed the relationship between enteric infections and malnutrition must be understood at a higher level than is currently expressed in current studies and existing literature.

Additional Resources:

Bennett, D., Naqvi, S. A. A., and Schmidt, W. P. (2014). *Learning, hygiene, and traditional medicine* (No. 14/25). HEDG, c/o Department of Economics, University of York.

Mbuya MN, Tavengwa NV, Stoltzfus RJ, Curtis V, Peltó GH, Ntozini R, et al. (2015). Design of an Intervention to Minimize Ingestion of Fecal Microbes by Young Children in Rural Zimbabwe. *Clin Infect Dis*. 2015;61 Suppl 7:S703-9.

Barriers to and Facilitators of ASF Consumption

Lifestyle Determinants to ASF Consumption

Alemu, Z.A., Ahmed, A.A., Yalew, A.W. (2016). Non-random distribution of child undernutrition in Ethiopia: spatial analysis from the 2011 Ethiopia demographic and health survey. *International Journal for Equity in Health*. 15:198.

Link: <https://doi.org/10.1186/s12939-016-0480-z>

The aim of this study was to understand the spatial epidemiology of child undernutrition in Ethiopia by identifying the SaTScan spatial clusters of child undernutrition in Ethiopia. The study showed geographical variability of child stunting, underweight and wasting in the country which demands risk based local nutritional interventions. The data used came from the 2011 Ethiopian Demographic and Health survey (EDHS). There were 9512 children (ages 0-50 months) in 571 EDHS clusters were considered for analysis. Results of the study indicated that 9638 under five children were considered and 2977 (30.88%) under five children were underweight and 6661 (69.11%) were not underweight children. The SaTScan spatial analysis identified seven SaTScan clusters as hotspot areas for child underweight in the order of severity. The primary SaTScan clusters were detected in the Northern, Middle, North east and Northwest areas of Ethiopia, particularly from all administrative zones of Amhara, Tigray, Affar, Ben. Gumz regional state administrative zones and East Welega and North Showa administrative zones, from Oromiya Regional State (LLR = 60.27, $p < 0.0001$). The most likely secondary SaTScan clusters were detected in Southeast areas of Ethiopia particularly from Liben, Afder, Borena and Gode administrative zones (LLR = 13.65, $P = 0.001$). In the third location, the SaTScan spatial analysis identified SaTScan clusters in Southern and central Ethiopia, particularly from East showa, Gurage, Kembata Alaba T, Hadiya, Sidama and Arsi zones (LLR = 10.03, $P = 0.024$). The results for stunting include 4149 (43.3%) children that were stunted. The SaTScan spatial analysis detected eight SaTScan clusters for child stunting. The most likely primary SaTScan clusters were detected around Northern, Middle, Northeast and North West areas of Ethiopia particularly from all administrative zones of Tigray, Amhara, Ben. Gumz and Affar regional states and West and North Showa and East Welega from Oromiya regional states (LLR = 97.28, $P < 0.0001$). The SaTScan spatial analysis result indicated the secondary most likely SaTScan clusters from Southern Ethiopia specifically from Borena and Gedeo Zones (LLR = 9.13, $p = 0.06$).

Azzarri C., Zezza, C., Haile B., Cross, E. (2015) Does Livestock Ownership Affect Animal Source Foods Consumption and Child Nutritional Status? Evidence from Rural Uganda, *The Journal of Development Studies*, 51:8, 1034-1059.

Link: <https://doi.org/10.1596/1813-9450-7111>

This paper explores whether ownership of different livestock species increases consumption of ASF and helps to improve child nutritional status (child weight and height) in Uganda. There is evidence that promoting small livestock ownership may have the potential to affect human nutrition. The authors used household survey data from the 2005/06 Uganda National Household Survey (UNHS) and the 2009/10 (7,421 households from 783 enumeration areas) Uganda National Panel Survey (UNPS) (2,975 households in 322 enumeration areas). These are nationally representative surveys, stratified random sample of the Ugandan population and contain information collected in a similar design including agricultural activities, socioeconomic information, demographic information and anthropometric information of CU5. Both surveys include detailed food and non-food consumption expenditure modules. The authors examined four categories of ASF (beef, chicken, dairy, sheep and goat meat) as well as an aggregate of all four. The livestock categories examined include large ruminants (bulls, cows, calves), small ruminants (goats and sheep), and poultry (chickens, turkeys, and ducks). The authors captured the effect of livestock ownership on ASF consumption and child nutrition outcomes by computing the annual value of per capita consumption as price times quantity consumed.

There were differences in consumption between livestock owners and non-owners. Livestock owners generally have a higher value as well as share of consumption of different ASF than the average household in the sample. Livestock owners consume more sheep and goat, and chicken meat per capita, and have higher shares of income from crop production and lower shares of income from wages. The number of animals owned and ASF consumption both increase with the level of expenditure. Under-five children in households that own livestock have higher WA, and WAZ, on average, than their counterparts in households without livestock. Average HAZ and WAZ are found to vary by expenditure levels.

Bekelman, T. A., Santamaría-Ulloa, C., and Dufour, D. L. (2019). Variation in dietary intake and body fatness by socioeconomic status among women in the context of Costa Rican nutrition transitions. *Journal of Biosocial Science*, 1-18.

Link: <https://doi.org/10.1017/S0021932019000403>

The purpose of this cross-sectional study was to compare adiposity and food consumption by socioeconomic status and assess the relationships between foods that contain high amounts of vegetable oil, ASF, or caloric sweeteners and body fat. The study included 128 non-pregnant non-lactating women between the ages 25-45 with 1-4 live births that were in low, middle, and high-income households in Costa Rica. Some of the factors that were considered in this study include BMI, dietary recalls, socioeconomic status, intake frequency, nutrition transition food, and anthropometry. A multivariate analysis was used to compare the relationships between socioeconomic status and anthropometric measures. Both skinfold measurements and the intake frequency of vegetable oil were greater within women in low socioeconomic status compared to those in high socioeconomic status. Although the ASF consumption did not vary between socioeconomic levels, there was a greater consumption of dairy products among women in high compared to low socioeconomic status. The study highlights a few limitations in the study the first being the inability to reproduce the skinfold that was recorded, the second was recall bias of patients when describing their diet, the third was how the study did not account for food portion size, and finally it was noted that the study design prevented a comparison between socioeconomic status and intake of nutrition transition foods as well as anthropometric measures.

de Bruyn, J., Ferguson, E., Allman-Farinelli, M., Msuya, J., Alders, R. Food composition tables in resource-poor settings: exploring current limitations and opportunities, with a focus on animal-source foods in sub-Saharan Africa. *British Journal of Nutrition* (2016), 116, 1709–1719.

Link: <https://doi.org/10.1017/S0007114516003706>

This article is a review of food composition tables (FCT) used in sub-Saharan Africa, examining the spectrum of ASF reported and exploring data sources for each reference. This study focuses primarily on whether databases are representative of national or regional diets and whether data may be considered of sound quality for the context in which they were used. Comparisons were made between compositional data from three high-income nations, and the implications of using data from different sources are discussed. Focus was given to three micronutrients (vitamin A, B12, folate) because their content in ASF items differed markedly between the references consulted. Databases meeting criteria for inclusion were West African FCT, A FCT for Central and Eastern Uganda, FCT for Use in The Gambia, FCT for Mozambique, Tanzania FCTs, Lesotho FCT, and 'Nutritive value of foods of Zimbabwe'. Lists of ASF were compiled (Meat and meat products, fish and shellfish, milk, eggs and insects were included in both raw and, where available, cooked or processed forms). The second aspect of the analysis was classifying the ASF entries according to the data source for each food item, based on types of compositional data as defined by Greenfield and Southgate. These include original analytical values (published literature or unpublished laboratory reports), imputed values (data are estimated from analytical values for a similar food or for another form of the same food), calculated values (yield factors and nutrient retention factors for the relevant cooking methods), data from other

sources, borrowed data, and data from unspecified sources. Entries were further categorized according to the region from which compositional data originated: Africa, the USA, the UK, Europe or Asia (Table 1). New references rarely provide new data (recycled from other databases, from analyses conducted decades previously and sourced from high-income countries) and have limited usefulness. Accurate information on the nutrient content of locally available food items will better guide work in nutrition-sensitive and cost-efficient interventions and enable the development of meaningful guidelines for improving dietary adequacy.

Christian, A.K., Marquis, G.S., Colecraft. E. K., Butler, L. Caregivers' nutrition knowledge and attitudes are associated with household food diversity and children's animal source food intake across different agro-ecological zones in Ghana. *British Journal of Nutrition* (2016), 115, 351–360.

Link: <https://doi.org/10.1017/S0007114515004468>

This study looked at testing the link between how caregivers' nutrition knowledge and attitudes influence food variety and availability in the household (thus affecting child diet). The primary outcomes of the current analysis were household dietary diversity, child ASF diversity and child ASF frequency. This study was conducted in Ghana, and the data used for the analysis was collected for the ENAM project, between 2006 and 2007, in 12 rural communities, nested in three different ecological zones (Guinea Savannah Zone, Forest Transitional Zone and Coastal Savannah Zone). Responses from 608 caregivers surrounding their household characteristics, nutrition knowledge and feeding attitudes as well as the dietary intake of their household and children 2 to 5 years old was collected. Household foods and children's ASF consumed in the past 7 d were categorized into one of 14 and 10 groups, respectively. The results of the multilevel analysis include 2/3 of the background characteristics of the study participants were low wealth status, with caregiver mean age of 32.8 years old, 12.8% were single and 52.1% have no formal education. Children were 28, 13.2 and 2% underweight, stunted and wasted, respectively. The mean dietary diversity of the household ranged from 4-14 with a mean of 10.6. Almost all households (99.7%) reported consuming cereals, followed by fats/oil (96.5%) non-green leafy Vegetables (93.8 %), green leafy vegetables (88.3 %), and nuts and seeds (87.7 %). The most common animal food group consumed was fish (98.4 %). Less than half of the households had consumed poultry (47.9 %) or dairy products (37.2 %). The intake of ASF varied widely among children; the ASF diversity score ranged from zero to 10 with a mean of 4.7. About 90 % of children consumed whole fish, followed by fish powder (71.5 %) and eggs (71.2 %). The least consumed types of ASF were bush-meats and snails (26.6 and 21.5%, respectively). Results varied across the ecological zones. Generally, 71.1% of the caregivers reported believing that their children needed to be fed 2 to 3 times/day. Reasons for having adult supervision during child meal times, feeding diverse foods, prioritizing a child to receive ASF and the perceived child benefits of ASF differed across zones ($P < 0.001$). Households with caregivers belonging to the highest tertile of nutrition knowledge and attitude scores consumed more diverse diets compared with those of caregivers in the lowest tertile group (11.2 vs 10); $P < 0.001$). After controlling for the effect of agro-ecological zone, caregivers' nutrition knowledge and feeding attitudes positively predicted household dietary diversity and the frequency and diversity of children's ASF intakes ($P < 0.001$). The number of years of formal education of caregivers also positively predicted household dietary diversity and children's ASF diversity ($P < 0.001$).

Fadare, O., Mavrotas, G., Akerele, D., and Oyeyemi, M. (2019). Micronutrient-rich food consumption, intra-household food allocation and child stunting in rural Nigeria. *Public health nutrition*, 22(3), 444-454.

Link: <https://doi.org/10.1017/S1368980018003075>

In this cross-sectional study, the determinants of household's micronutrient-rich food consumption and the combined effect of vitamin A supplementation as well as the micronutrient-rich food consumption on child stunting in households with different food allocation patterns were examined.

The study took place in the rural setting in Kwara State, Nigeria which included 419 children aged 6-59 months of age across 413 households. Linked-scale questions were incorporated to assess the intra-household food allocation patterns while the micronutrient intakes measurements were collected on household food intake frequency over a 6-month period. The study also incorporated a logistic model to identify micronutrient-rich foods in households and investigate factors of child stunting. Some of the factors included with the study are household size, refrigerator ownership, access to improved drinking water, livestock holdings. Results indicated that owning small livestock and a refrigerator, being knowledgeable about micronutrient-rich foods, and higher parental education all associated with the consumption of micronutrient-rich foods. It also showed that a household that incorporated micronutrient-rich food and a diverse diet led to a less likelihood of stunting. In some cases, micronutrient supplementation to children that have poor access to micronutrient-rich foods did not show much growth and in other cases, micronutrient-rich foods did not reduce child stunting.

Kim, S. S., Nguyen, P. H., Tran, L. M., Abebe, Y., Asrat, Y., Tharaney, M., and Menon, P. (2019). Maternal behavioural determinants and livestock ownership are associated with animal source food consumption among young children during fasting in rural Ethiopia. *Maternal and child nutrition*, 15(2), e12695.

Link: <https://doi.org/10.1111/mcn.12695>

This study looks into the Lent fasting period in West Amhara, Ethiopia and how it influences ASF consumption among children. A baseline survey was distributed among family members with children within 6-23 months of age and applied to regression analysis to investigate how maternal and household factors might influence the child's diet of ASF. Some of the factors within the study include demographic characteristics, household food security, behavioral norms, and social norms. Although 80% of the sample population owned livestock animals, only a quarter of the children within the sample consumed ASF during the Lent fasting period. Some of the factors that influenced this reduction on ASF consumption were concerns about the stigma that could be invoked from outsiders, cooking utensils that could become contaminated, meat that was either not available or too expensive, and the wastefulness of slaughtering an animal just for a child. The authors go further to identify that even though a household may own livestock, ASF consumption within the family might still be low due to the financial gain that could be brought in by selling it in the market. Even though livestock ownership is a great factor that influences an ASF diet within the household, the study also shows the importance of maternal knowledge, beliefs, and perceived social norms that could affect ASF consumption among children. A limitation of the study includes the inability of the study to establish any causal relationship between behavioral factors or livestock ownership and ASF consumption due to the cross-sectional design of the data.

Marinda, P. A., Genschick, S., Khayeka-Wandabwa, C., Kiwanuka-Lubinda, R., and Thilsted, S. H. (2018). Dietary diversity determinants and contribution of fish to maternal and under-five nutritional status in Zambia. *PLOS ONE*, 13(9), e0204009.

Link: <https://doi.org/10.1371/journal.pone.0204009>

This is a cross-sectional study that assesses women in reproductive age and children in 6-59 months of age living in a poor urban settlement in Zambia called Lusaka. It investigates the socioeconomic determinants of food intake and their outcome in nutritional status. A three stages randomized sampling approach was used on 714 mother-child dyads that were enrolled. Some of the factors included in the study are the dietary diversity of women, consumption of fish, and consumption of food groups. Although fish was the most consumed ASF, the study found that consumption of fish among women was below the global average. Unlike other studies where they showed a wealthier child more likely to be overweight/obese, the study found that poor children were more likely to be overweight/obese due to low nutritious processed food that's cheap and easily accessible. The study pushes for further research and writes that incorporating more fish in the diets of children in poor

urban households is important. The study concludes that even though poor nutrition is a problem that needs to be solved, government and developmental partners will need to also investigate the rising obesity/overweight problem plaguing low-income children living in urban areas. Some of the limitations with the study include the inability of the study to compare dietary diversity and socioeconomic factors as well as the causality of fish consumption and nutritional status due to the cross-sectional nature of the study.

- Mosites, E. M., Rabinowitz, P. M., Thumbi, S. M., Montgomery, J. M., Palmer, G. H., May, S., ... and Walson, J. L. (2015). The relationship between livestock ownership and child stunting in three countries in eastern Africa using national survey data. *PLOS ONE*, 10(9), e0136686.**
Link: <https://doi.org/10.1371/journal.pone.0136686>

Programs based on livestock production or livestock gifts are often implemented within rural areas in developing countries, as potential to improve child nutrition is increased with livestock ownership. This study used pre-existing Demographic and Health Survey (DHS) datasets collected in Ethiopia, Kenya, and Uganda to analyze the relationship between child stunting and livestock ownership, as evaluations of this direct relationship were found to be uncommon. The DHS provided data on a variety of different animals and their prevalence in households across East Africa; however, authors chose only to include the number of owned cattle, chickens, sheep and goats within this study, as they were found to be the most commonly-owned livestock across all three countries. In order to control for variables with the potential to modify the relationship in question, the association between livestock ownership and child stunting was stratified by diarrheal disease, region, wealth index, and animal source food intake. Children from 0 to 59 months of age were included in the study, and were defined as stunted if the child had a height-for-age z score of less than -2 standard deviations below the 2006 WHO reference mean. When using a log-binomial model to create comparative prevalence ratios, the authors found a statistically significant association between a ten-fold increase in livestock count and decreased stunting prevalence in Ethiopia and Uganda, but not in Kenya. A second way in which the study compared livestock ownership to child stunting used a weighted measure known as a Tropical Livestock Unit (TLU), which combines multiple animals into a single weighted measure based on market value and total body weight. The prevalence of stunting appeared to be lower in households with higher TLUs, but the association was not statistically significant. Within each country the authors analyzed possible relationships between ownership of one specific species and child stunting, but it was found that no single species was individually associated with an increase in stunting. Overall, the study found a general trend towards a protective association between livestock ownership and child stunting in most of the analyses conducted. It is noted that a longitudinal study looking at similar variables could allow us to learn more about the dynamics of the relationship between livestock ownership and child stunting, such as the specific influence in varying critical growth windows.

- Potts, K. S., Mulugeta, A., and Bazzano, A. N. (2019). Animal Source Food Consumption in Young Children from Four Regions of Ethiopia: Association with Religion, Livelihood, and Participation in the Productive Safety Net Program. *Nutrients*, 11(2), 354.**
Link: <https://doi.org/10.3390/nu11020354>

This study identifies factors within the household and the community that is associated with the consumption of animal-source foods among children who are 6 to 36 months old in four regions of Ethiopia. Factors considered in the study were demographic information, proxy indicators of socioeconomic status, age, livelihood, and religion. An increase in age, pastoral livelihood, Muslim religion, and participation in the Productive Safety Net Program were all associated with increased consumption of ASF. As age increased by 3-months, the consumption of ASF increased as well. Pastoral children had an increased likelihood of consuming ASF in the last 24 hours followed by agropastoral children, then agriculturalist/farming children. The study concludes by highlighting the importance of incorporating variables such as local context as well as community characteristics like

livelihood and religion when creating interventions that aim to improve the diversification of a child's diet with the incorporation of ASF. It is also noted by the authors that the Productive Safety Net Program could be a critical determinant of dietary diversity for the children living in Ethiopia. Some of the limitations included within the studies were the data collection errors that excluded participants from being in the study, limited measures of socioeconomic status, and the limited scope of questions that didn't capture food insecurity.

- Rakotonirainy, N. H., Razafindratovo, V., Remonja, C. R., Rasoloarijaona, R., Piola, P., Raharintsoa, C., and Randremanana, R. V. (2018). Dietary diversity of 6-to 59-month-old children in rural areas of Moramanga and Morondava districts, Madagascar. *PLOS ONE*, 13(7), e0200235.**
Link: <https://doi.org/10.1371/journal.pone.0200235>

This study aimed to identify the dietary practices of children and to discover the determinants of low dietary diversity to bring about a nutritional intervention in rural areas of Moramanga and Morondava, Madagascar. The study randomly chose 1824 children from thirteen villages and separated into two study areas (893 from Moramanga and 931 from Morondava). The child's anthropometric measurements were collected and then a random sampling of non-malnourished and stunted children was performed until 810 children were collected from each study site. A 24-hour recall method was implemented to collect data pertaining to household characteristics, mothers, and children who were 6-59 months of age to identify chronic malnutrition. Bivariate and multivariate analysis was conducted to determine what was causing low dietary diversity scores for the children. Some of the factors in the study include anthropometric measurements, household characteristics, socioeconomic status, and livestock ownership. The study indicated about 42% of children in Moramanga and 47% of children in Morondava showed signs of a poor diversity diet. Many diets consisted of high charophytes and low meat. The odds ratio for low educated mothers and a non-varied diet was 2.2 while low household income and living in a household without livestock were associated with a low dietary diversity with a score of 1.8. The study highlights the greater need to provide nutritional education and create poverty reduction programs. Some of the limitations of the study are the small sample size and the lack of seasonality information in the study.

- Sebayang, S.K., Dibley, M.J., Astutik, E., Efendi, F., Kelly, P.J., and Li, M. (2019). Determinants of age-appropriate breastfeeding, dietary diversity, and consumption of animal source foods among Indonesian children. *Maternal and child nutrition*, e12889.**
Link: <https://doi.org/10.1111/mcn.12889>

This study investigated the determinants of age-inappropriate breastfeeding, dietary diversity, and three different groups of ASF in children between the ages 0-23 months old within Indonesia. The study used 11,687 observation data from the Indonesian Demographic Health Survey (2012 and 2017) which was analyzed using Stata 15 by applying a linear and logistic regression and adjusting for the complex sampling design. Some of the factors included in the study are socioeconomic status, education, regional differences, and antenatal care. While age and quality of antenatal care were associated with all outcomes, socio-economic status and labor force participation were positively related to higher dietary diversity, ASF consumption, and age-inappropriate breastfeeding. Children who were between the ages 0-5 months old had a greater odd of being age-inappropriately breastfed, but children who were 6-17 months old had about 50% lower odds of being inappropriately breastfed than children who were 18-23 months old. It was also identified that the greater knowledge level, as well as the higher frequency of antenatal care visits, were associated with more dietary diversity. Although the study incorporated a large sample size, due to the cross-sectional design of the study, the results aren't able to show causal relationships. The study also notes that the lack of measurements that tracked the mother's participation in postnatal care prevented a better way to track the mother's use of health services.

Workicho, A., Belachew, T., Feyissa, G.T., Wondafrash, B., Lachat, C. Verstraeten, R. and Kolsteren, P. (2016). Household dietary diversity and Animal Source Food consumption in Ethiopia: evidence from the 2011 Welfare Monitoring Survey. *BMC Public Health*. 16:1192. Link: <https://doi.org/10.1186/s12889-016-3861-8>

This study identified predictors of household dietary diversity in Ethiopia and pattern of consumption of animal source food (ASF) among 27,995 households using secondary data from the 2011 Ethiopian Welfare Monitoring Survey (WMS). This survey used a structured questionnaire to collect socio-demographic and economic data. Dietary data in this study was collected using a dietary diversity questionnaire that measured dietary diversity over the past 1 week. A Household Dietary Diversity Score (HDDS), constructed according to the FAO guidelines, had consumption of ASFs described by its distribution among the regions and by HDDS. Multiple logistic regression analyses were used to identify independent predictors for HDDS. This study identified those households from urban areas and high socio-economic groups have a more varied diet.

Climate Change Barriers

Cherotich, V. K., Saidu, O. S. E. N. I., and Bebe, B. O. (2012). Access to climate change information and support services by the vulnerable groups in semi-arid Kenya for adaptive capacity development. *African Crop Science Journal*, 20(2), 169-180. Link: <https://www.ajol.info/index.php/acsj/article/view/81711>

The purpose of this study had four main objectives centered around distinguishing the networks through which vulnerable women (aged 24-60) and elderly adults (equal to or older than 65 years) gain access to climate information and support services in the semi-arid region of Kenya.

1. Determine the vulnerable population's perception of climate change and impacts of climate change for the past five years.
2. Distinguish the support services and information provided by those services that the vulnerable population is actually accessing
3. Identify the information dissemination pathways which the vulnerable population views as the most reliant delivery of pertinent climate change information
4. Determine the attributes of the dissemination pathways which are utilized most due to their user-friendly nature

For the purpose of this study, 4 different information conduits were examined in conjunction with who puts out that form of media (listed in parentheses)—Mass Media (Researchers), Print Media (Meteorological Department), Electronic Media (Indigenous Knowledge), and Community Channels (Development Agencies). In order to meet the study objectives, the authors conducted a cross-sectional survey utilizing a questionnaire with a sample size of 19,443 participants. The questionnaire asked the participants their *perceived severity* of change in 7 areas—drought, floods, heat stress, human disease, livestock disease, rainfall variability, and temperature change—within the defined severity categories on a Likert scale (1-5, respectively) of no change, mild change, moderate change, severe change, and very severe change. The data was analyzed by dissemination pathway by performing a Principal Component Analysis (PCA) due to the high correlation among the variables of interest. Proportional differences of chi-squared values were attained through cross-tabulation. Findings showed that the just over 70% of the vulnerable population in the study sample perceived the effects of climate change to have had both “severe” and “very severe” impacts on drought, floods, human disease, livestock disease, and rainfall within the past five years. The vulnerable populations of women and the elderly had different preferences for information, with women preferring radio ($p < 0.05$) and the elderly relying heavily on information through more in PCA showed that a comprehensive informational network on climatic hazards and support services offered better adaptation capabilities via extension services. Overall, the authors determined that a combination of information networks, consisting of radio, extension agents, and local administration, would be the most effective joint pathway for dissemination

information regarding climate information, as well as support services needed by the vulnerable population.

Johnson, K. and Brown, M.E. (2014). Environmental risk factors and child nutritional status and survival in a context of climate variability and change. *Applied Geography* 54:209-221.

Link: <https://doi.org/10.1016/j.apgeog.2014.08.007>

This article assesses the impact of climate on nutrition outcomes in West Africa. Stunting, wasting, and mortality are affected by climate in Mali and Burkina Faso. Wasting and mortality due to climate effects was seen in children in Benin. Using NASA's satellite remote sensing data with Demographic and Health Surveys (DHS) and data from four West African countries (Mali, Burkina Faso, Guinea and Benin), the authors assess the association between a climate-related environmental variable (vegetation index - NDVI) and child survival and nutrition. NDVI had a positive association with child survival and nutrition in countries with a wide distribution of NDVI values. NDVI was more likely to be positively associated with wasting rather than stunting.

Kratli, S., Huelsebusch, C., Brooks, S., Kaufmann, B. (2013). Pastoralism: A critical asset for food security under global climate change. *Animal Frontiers*. 3(1): 42-50.

Link: <https://doi.org/10.2527/af.2013-0007>

This article aimed to address the economic importance of pastoral production in arid and semiarid areas in Africa and compared these with other production systems in the same conditions. It focuses on the pastoral system of production and provides evidence of the contribution it makes to food security in these areas because pastoralists take advantage of the instability of rangeland environments and the variability in the drylands that may pose a threat to sedentary agriculture or even mixed farming. The authors also consider the current and prospective constraints to the potential of pastoral production in relation to food insecurity since the pastoral system itself is vulnerable to manage and operate within the current political and business systems that tend to want to replace pastoralism with other systems of food production. These include alienation of pastoral resources, agricultural land tenure reforms, undermining of pastoralists sociocultural values, codes of conduct, and institutions, as well as increasing conflicts by replacing diversity and complementarity between the different production systems. The authors go a step further to examine several options that might enhance the contribution pastoral production is able to make, to both food security and economic prosperity in the region. These include: properly managing the nomadic pastoral livestock production to improve environmental compatibility and agricultural sustainability and production in drylands, improving mobility, improving livestock feeding selectivity, fostering the variety of livestock species kept (diversification), modernizing by developing technologies capable of assisting sustainable and strategic mobility and feeding selectivity, and increasing formal education for pastoralists.

Ziervogel, G. , Bharwani, S. and Downing, T. E. (2006), Adapting to climate variability: Pumpkins, people and policy. *Natural Resources Forum*, 30: 294-305.

Link: <https://doi.org/10.1111/j.1477-8947.2006.00121.x>

Authors Ziervogel, et al. argue that understanding climate variability and how it relates to the concept of adaptation, is crucial to effectively address vulnerability and human insecurity. The authors conducted a case study in Mangondi Village, South Africa, where a communal, irrigated farming project was piloted by the Department of Welfare. The point of the project, to empower women through the production of vegetables in order to feed their children. The case study concluded that fluctuating climate caused various results, projected by the quantity of goods produced. The variability of stressors that these communities were adapting to exemplify a complicated nature that does not limit itself to a single stressor (climate), rather a ranging number of stressors. When fabricating strategies for effective intervention, it become salient other factors need to be addressed. Seasonal forecast being a primordial

stressor for food production and adaptation, reflected by poorer farmers which fall into a disadvantageous contingency due to a lack of accessibility to resources. Ziervogel, et al. pressure the reader to focus less on climate change, although a big factor, and more on outlying factors such as market variability, socioeconomic and sociocultural contingencies which directly affect proper adaptation to one's environment and can all be exacerbated via a changing climate. The key is to develop increased resilience to reduce the negative consequences of overall stressors prevalent in South Africa—climate included.

Additional Resources:

Gerber, P. J., Steinfeld, H., Henderson, B., Mottet, A., Opio, C., Dijkman, J., ... and Tempio, G. (2013). *Tackling climate change through livestock: a global assessment of emissions and mitigation opportunities*. Food and Agriculture Organization of the United Nations (FAO).

Kariuki, J., Njuki, J., Mburu, S., and Waithanji, E. (2013). Women, livestock ownership and food security. *Njuki et al*, 95-110.

Importance of Gender in ASF Consumption

Ahmed, S., and Fajber, E. (2009). Engendering adaptation to climate variability in Gujarat, India. *Gender and Development*, 17(1), 33-50.

Link: <https://doi.org/10.1080/13552070802696896>

This paper highlights the importance of collaboration between researcher and practitioners to better understand the nuances in gendered vulnerability to the effects of climate change. The Indian government has put into place the National Action Plan on Climate Change (NAPCC) in hopes of addressing the concerns the government has on climate change in relation to India's vulnerable populations of children, elderly, and women. The authors discuss the lack of "long-term climate-resilient development" in the developing world, India included. Many implemented programs have, instead, been centered around relief and rehabilitation. The authors reference the development of the Institute of Social and Environmental Transition, which is a collaborative effort between organizations comprised of development practitioners and researchers. ISET is focused on the goal of adaptation, which the authors highlight is important for equally understanding vulnerability and what populations must be adaptable to survive the effects of climate change. Authors discuss the main issue of vulnerability measurements as a lack of approach, in which vulnerability is viewed as a dynamic process and not a stagnant item—the less conspicuous factors include resource tenure and change in human attitudes. In a parallel response to ISET, authors have created a quantitative vulnerability index for vulnerability, which include 11 'drivers of vulnerability' at household, community and rural/urban community levels. The Vulnerability Capacity Index (VCI) to aid in the testing and assessment of vulnerability. The authors chose the state of Gujarat, India, because it is the state with the longest coastline. Gujarat is extremely biodiverse; however, it is subject to many extreme weather events—cyclones, flooding, draught, and salinity intrusion. As a result, to these issues, development organizations were created by the community—Utthan and People's Learning Centre for Livelihood Security and Disaster Mitigation in Coastal Communities (PLC-Coastal). With the community organizations working as key partners, three pilot projects were assed in three different villages, all of which periodically experience, drought, salinity, and cyclones. The livelihood portion of this project sought to intervene with the livelihood loss of poor farmers, whose agriculture was suffering due to salinity intrusion. The project had 3 parts in order to help facilitate adaptation: 1. Livelihood diversification, 2. Adaptive infrastructure for water and sanitation, and 3. Capacity-building for disaster governance. At the time of publication, the studies and projects in Gujarat served as insight to the authors as to approaches for interventions for adaptability and measuring vulnerability. Results showed

that engendering strategies for adaptation continue to be a barrier to overcome, and that engendering processes and strategies should be the priority of focus moving forward in adaptation.

Denton, F. (2002). Climate change vulnerability, impacts, and adaptation: Why does gender matter? *Gender and Development*, 10(2), 10-20.

Link: <https://doi.org/10.1080/13552070215903>

This opinion piece is written to discuss the importance of all stakeholders, including women and the poor, into the implementation of sustainable development and policies regarding sustainable development—especially regarding the Kyoto Protocol. Denton argues that women play a key role in the sustaining of their homes and land, yet are often overlooked in the target audience of policies. The United Nations Framework Convention on Climate Change (UNFCCC) discussed the lack of women representation during the Seventh Conference of Parties (CoP7). During the CoP7, it was decided that the Kyoto Protocol would institute a protocol to ensure the participation of women in discussions and decision-making. Unfortunately, Denton points out how the inclusion of women does not necessarily mean that the issues facing women will actually be addressed. Continuing, Denton discusses that less developed countries (LDC) will have a hard time recovering from catastrophic events in order to reach a level of sustainment. Denton concludes that the epicenter of sustainable development is women, and that gender equality in all sectors of development would benefit the world, as a whole. Nations who are poorer have difficulty getting wealthier nations to meet obligations that work toward climate mitigation. This key factor is one that can affect women, the poor, and (most of all) poor women in regard to means—lessening the diversity available to supplement family livelihoods and welfare.

Doka, M. D., Madougou, D., and Diouf, A. (2014). Food Crisis, Gender, and Resilience in the Sahel: Lessons from the 2012 crisis in Burkina Faso, Mali, and Niger. Oxfam International.

Link: [Doka](#)

This report was written for Oxfam Research Reports with the main intent being to assess survey given to evaluate the response to the food crisis of 2012 in the Sahel, particularly in Burkina Faso, Mali, and Niger. This report was a direct reflection on the surveys performed, as well as previous work and statements made by the local community members, and serves to provide humanitarian groups and governmental programs with insight into future programs. The Sahel region, like many other areas of the world, has intrinsically defined gender roles. In this society, the role of women as earners and contributors to the household is often overlooked; however, the role of women has proven to be integral to survival in a crisis. Because the roles of women are downplayed within the society, women have a difficult time accessing factors of production and are not part of community-based administration. This research sought to discover the ways in which food security could be strengthened through women, and to assess the response of the food crisis in the Sahel. To accomplish the goals of the research, a preliminary literature review of the food crisis documentation was performed to better understand the situation in the Sahel. The following objectives were identified for the research:

“(1) Record and analyze gender-linked vulnerability, (2) Understand how gender-specific norms and roles interact with other factors to increase vulnerability to food insecurity in men and women of all ages, (3) Identify short-term and long-term responses that could help reduce gender-based vulnerability and enhance resilience of women and girls, through better access to resources, decision-making bodies, and leadership.”

Researchers surveyed a total of 13 communities from the countries of Burkina Faso (5), Mali (4), and Niger (4). Two inclusion criteria needed to be met for selection; the criteria were that the community must have been affected by the 2012 food crisis and have received humanitarian aid. The data was collected in a qualitative and quantitative manner, and data collection opportunities were extended to all stakeholders in the communities. Individuals were selected based off their individual knowledge-

level and ability to answer questions. A total of 40 individual questionnaires were conducted per community, and a qualitative interview was conducted with 8 groups per community.

The survey and interview findings confirmed the food crisis in the Sahel was caused by many factors including, but not limited to, “climatic events in arid or semi-arid zones, imbalance between needs and resources, armed conflict, cattle disease, crop pests, etc.” Survey results showed a barrier to accessing the factors of production, as well as a lack of women in community decision-making bodies. This lack of access and prevention of responsibility makes a food crisis increasingly more difficult for women to weather. Additionally, the unspoken norm among society is for women to earn an income performing “income-generating activities” (IGAs) or contribute to the family’s food production—the women feel this is becoming necessary for the survival of their families. Research has shown that women who can negotiate or influence the household decisions improve the food overall, long-term food security of the household. The researchers concluded that the best way to increase food security and resiliency during a crisis in the Sahel is to begin acknowledging the roles that women play in the communities and allowing women more access to means of production as well as roles in community management.

Kariuki, J., Njuki, J., Mburu, S. and Waithanji, E. (2013) "Women, livestock ownership and food security." In *Women, livestock ownership and markets*, Njuki, J. and P. Sangigna, Editors: 95.

Link: [Kariuki](#)

This brief highlights main takeaway points from the chapter, “Women, livestock ownership and food security,” in the book *Women, Livestock Ownership and Markets* produced by the International Livestock Research Institute (ILRI). To examine food security, the authors define it as, “...[W]hen all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life.” The purpose of this brief is to discuss the contributions that livestock play in food security.

- Facilitating direct access to eggs, meat, milk, etc.
- Providing money from sale of livestock and/or livestock products, which can be used to purchase household food in times of shortage.
- Contributing to increased grain yields due to improved productivity from use of manure and traction.

The authors highlight the fact that intra-household dynamics contribute to food security, and the extent that women can influence household decisions plays a large part. Though societal norms are expected, each household may have variability within its decision makings or deviations from societal norms. Authors discuss that the assets that women own are not only fewer than men, but utilized differently. The increase in women’s control over their assets has been shown to have a positive correlation with food security, and childhood nutrition and education. The authors concur that their studies and research concur with others, revealing positive relationships between the ownership of livestock and the food security of a household—noting that the livestock species and patterns of ownership are equally significant in the relationship to household food security. Findings showed that:

- Households owning goats and exotic chickens had diets twice as diverse as households not owning those species.
- When compared with households keeping traditional chickens, households keeping exotic chickens generated income from the sales of exotic chickens allowed households to purchase food in greater diversity, allowing for more variability within the diet.
- Households keeping exotic chickens consumed significantly more eggs than households not owning exotic chickens.
- No significant differences were found between households that did, or did not, own local chickens.

The authors continue to illustrate that smallholders in rural communities rely on the “cash economy” the sale of livestock provides the household. Using Mali as an example, where 78% of cash income for smallholders is generated from livestock. Though this income is generated, it has not been found to purchase bulk food to ensure food security during times of food scarcity. This prevents a challenge of spending norms. Regarding livestock ownership, authors discuss how the ownership of livestock by women increases the likelihood that women will make decisions on that livestock, as well as income generated from it. When women are empowered with these decisions, studies show that women are more likely to diversify the diet and ensure food security for the household; however, this point circles back to intra-household dynamics. Results showed that households where women owned livestock were “considerably” higher to consume meat frequently, versus households where women did not own livestock.

McKune, S. L., Borresen, E. C., Young, A. G., Ryley, T. D. A., Russo, S. L., Camara, A. D., ... and Ryan, E. P. (2015). Climate change through a gendered lens: Examining livestock holder food security. *Global Food Security*, 6, 1-8.

Link: <https://doi.org/10.1016/j.gfs.2015.05.001>

This review looks at adaptive capacity, exposure, and sensitivity to climate change, and vulnerability through a “gendered lens” to discuss the impacts on livestock producers. The authors discuss the socioeconomic and environmental factors that affect food security due to climate change, and in particular the importance in the gendered experiences of men and women, especially amongst livestock holders. The authors propose and discuss a gendered framework, highlighting potential vulnerability pathways and intervention points, which global health strategists can utilize for implementing and improving food security within households. Authors state that an estimated 60% of rural households maintain livestock, globally. Due to climate change, these smallholders are experiencing an increase in the unpredictability of sustainability, resulting in an increase of malnutrition and food insecurity. The authors define their conceptual relationships and terms of their gendered framework. The effects of climate change on agropastoralists, pastoralists, and urban livestock holders are discussed. The authors discuss the challenge affirmed by Marcoux in separating the relationship between poverty and gender, which affects the adaptive response of livestock holders to climate change. Limitations to empirical analysis include the lack of gender-disaggregated data, as well as society-based nuances that can affect the ownership and value of livestock. Authors argue that this lack of data has caused an “oversimplification of women and men’s experience of climate-change related events”. In conclusion, authors stress the importance of understanding how livestock holders’ new strategies for climate change adaptation can be accepted and incorporated into the livelihoods of various stakeholders. This paper serves as a good reference for climatologists, global health practitioners, and nutritionists who are working toward a gendered approach on improving the food security and adaptive capacity of livestock holders through interventions.

Nelson, V., and Stathers, T. (2009). Resilience, power, culture, and climate: a case study from semi-arid Tanzania, and new research directions. *Gender and Development*, 17(1), 81-94.

Link: <https://doi.org/10.1080/13552070802696946>

Authors Nelson and Stathers write about the different ways climate change will affect men and women in Tanzania, and how prevalent gender norms and empowerment inequalities shape the facility to which men and women adapt to unpredictable climate. The authors explain integrating women into active decision making and thus reducing the gender gap, would make significant changes in climate induced adaptations and in national/sub regional mitigation. As crop production increasingly changes, due to varying biophysical agricultural patterns, the gendered division of labor will expose men and women to different levels of risks. The authors suggest these different forms of knowledge, due to gendered division of labor, should be combined to maximize resource coping when it comes to climate change: a Bolivian project on the Aymara communities intersected men and women’s knowledge on

agricultural development, female *yapachuris* stored vegetables, medicines and were taught to monitor bio-indicators of climate. Resilience based thinking is reinforced throughout the article, an actor-theory network, where we are all acting on, contributing or playing role in socio-ecological dynamics, that surpass gender based assumptions; nonetheless, different societies adopt different norms, which makes it difficult to assume all societies could function this way.

Young, A., McKune, S. L., Russo, S. Ryley, T. D., and Camara, A. D. (2012). The nexus of gender and nutrition: A literature review. *Livestock-Climate Change CRSP*, 3.

Link: [Young](#)

The authors present that climate change makes livestock rearing difficult and many pastoralists must seek new livelihoods. Some strategies noted that pastoralists may engage in due to climate change include diversifying income-generating activities or caring for smaller ruminants. The transition to smaller livestock has nutritional implications as there are fewer essential nutrients for consumption. The authors mention the impact seasons have on the type of diet these communities engage in; drier seasons mean more grain-based diets, which have more caloric value but less protein. The authors explain the influence on gender a shift in livelihood has. As men begin to travel to find work, women become heads of the household and take on more roles. Gender negatively influences economic opportunities as well. During a climate change event, men distancing themselves from environmental activities and women becoming more dependent on them, which causes them to have different ideas on long-term strategies to reduce the impact on their families. Another coping mechanism mentioned in the text includes short-term coping strategies such as exchanging higher caloric livestock for low caloric cereals. The authors provide that there are non-food factors that influence malnutrition as well such as education status or disease prevalence. The four direct pathways climate change impacts nutrition are listed: climate change can create low crop yields which leads to undernutrition; changes in temperature and weather can lead to disease outbreak; undernutrition and disease lead to an inability to perform physically demanding tasks; and undernutrition increases susceptibility to disease. Women's lack of agency is detailed through various examples such as men deciding on course of medical treatment of children or deciding when women will give birth. Overall, the authors advocate for more equal ownership and decision making for women in households to aid in diversifying diet and stabilizing household food security.

Waters, W. F., Gallegos, C. A., Karp, C., Lutter, C., Stewart, C., and Iannotti, L. (2018). Cracking the egg potential: traditional knowledge, attitudes, and practices in a food-based nutrition intervention in highland Ecuador. *Food and nutrition bulletin*, 39(2), 206-218.

Link: <https://doi.org/10.1177/0379572118763182>

This study used a qualitative component to understand local perception, knowledge, and practices to build on a randomized control study conducted in a rural community in Ecuador which assessed the effects of introducing eggs on nutritional status and growth in children who were 6-9 months of age. The data collected from the study was extracted from key informant interviews, focus group discussion, and structured observation. Key informant interviews were conducted privately without observers while focus groups were designed to incorporate members of the treatment group, members of the control group, members of both groups, and community members who were not participating in the project. Some of the factors within the study included local household diets, perception of egg quality, preparation, and consumption. Household egg quality was perceived to be better from small-scale producers compared to supermarkets and commercialized operations. Eggs were prepared in various ways and were also given to children in mixed beverages to improve their performance during exams. Although the poorest population in the community had significant barriers to obtain an egg per day, the study found that low costs of eggs allow consumption or production of eggs within each household to be feasible. Some of the limitations of the study include the lack of random participant selection.

Families and individuals were selected either because they were familiar with the study areas or because they were perceived to represent the norm in Ecuador.

Additional Resources:

Allen, L. H. (1993). The nutrition CRSP: What is marginal malnutrition, and does it affect human function? *Nutrition Reviews*, 51(9), 255-267.

Kakota, T., Nyariki, D., Mkwambisi, D., and Kogi-Makau, W. (2011). Gender vulnerability to climate variability and household food insecurity. *Climate and development*, 3(4), 298-309.

Nelson, V. (2011). Gender, generations, social protection and climate change: A thematic review. *Overseas Development Institute, London*.

Programs to Increase ASF Production and Consumption

Aakesson, A. (2017, March). Effective behavior change messaging to increase consumption of animal-source foods. *Nurturing development: Improving human nutrition with animal-source foods*. Symposium conducted at the University of Florida, Gainesville, FL.

Link: [Aakesson](#)

The author explains the importance of using messages to affect behavior change. Because messaging is not enough to change behaviors, the focus should be on identifying who influences household food consumptions, their actions that influence consumptions and what they could do differently to consume more nutritious foods. The pathways of food consumption, income invested in purchasing nutritious foods and health and WASH, and the influence of gender. The author indicates the need to identify risks and benefits, especially objectively. Factors such as barriers and facilitators should also be considered. Examples and guidelines of messages for increasing animal-source food consumption include promoting animal-source foods in local terms by what the consumers value in food, associating animal-source food consumption to risks and benefits, making the messages emotionally and cognitively interesting, and enabling environments that will allow for behavior change.

Bertram, R. (2017, March). Improving nutrition, resiliency and productivity: The perspective of the Food Security Act. *Nurturing development: Improving human nutrition with animal-source foods*. Symposium conducted at the University of Florida, Gainesville, FL.

Link: [Bertam](#)

The speaker identified the Food Security Act as building up the success of the Feed the Future initiative and serving to institutionalize the goal of improving food security and nutrition. The framework for the act focuses on the objectives of creating inclusive and sustainable agriculture-led economic growth, strengthening resilience among people and systems, and helping populations become well-nourished. The speaker highlights the multi-faceted issue of malnutrition has been found to be influenced by three key mechanisms: food, water and sanitation, and women's education and status. Potential methods for increasing production which may lead to improved consumption and nutrition are mentioned. It is also noted that variables that may affect intervention components should be considered and efforts to create sustainable developments are key, especially for smallholder farmers.

Borin, K. (2017, March). Improving availability of ASF: Challenges and opportunities. *Nurturing development: Improving human nutrition with animal-source foods*. Symposium conducted at the University of Florida, Gainesville, FL.

Link: [Borin](#)

The speaker provides the importance of engaging producer interest to increase availability of animal-source foods as they respond to the demands in the market. It is presented that availability can be increased through technologies, capital, and extension. The speaker illustrates the context of Cambodia where there are subsistence farmers with little production to local markets, self-sufficient farmers who produce a single commodity for the market, and large farms with contract farming. The speaker presents some constraints farmers face such as limited capacity to solve technical issues, limited access to quality veterinary and extension services, and inadequate capital, insurance, risk reduction tools, and market information. The author cites a review paper which concluded that there are technologies available for farmers, but utilization is limited. The speaker concludes which questions to consider for project leader: what drives animal-source food production, where to start when the target is smallholder farmers, how can livestock production be promoted efficiently and effectively, and what is the best way for knowledge to be generated and shared by farmers.

Coates, J.C., Colaiezzi, B.A., Bell, W., Charrondiere, U.R., and Leclercq, C. (2017). Overcoming Dietary Assessment Challenges in Low-Income Countries: Technological Solutions Proposed by the International Dietary Data Expansion (INDDEX) Project. *Nutrients*. 9(289). Link: <https://doi.org/10.3390/nu9030289>

This article was a discussion paper that firstly, sought to highlight the barriers to collection and use of individual-level dietary data in low-income countries. Secondly, illustrate that improvements and investments in research infrastructure (i.e. data collection instruments, knowledge-containing resources such as e-platforms and data banks, data management protocols and knowledge transfer), new technology (i.e. INDDEX24 platform, a dietary recall mobile app and linked web database), and capacity development by using the International Dietary Data Expansion (INDDEX) project can remedy these barriers. Thirdly, this paper highlighted areas of global need that will require additional partnerships and resources to ensure open access and that stakeholders are involved in the intention and design of each tool, trainings, and capacity development through virtual regional working groups and workforce development.

Dumas, S. E., Lewis, D., and Travis, A. J. (2018). Small-scale egg production centres increase children's egg consumption in rural Zambia. *Maternal and child nutrition*, 14, e12662. Link: <https://doi.org/10.1111/mcn.12662>

In this study, an intervention was piloted to target Zambian communities by formulating 20 groups that would create egg production centers to identify program impact on egg consumption and household egg acquisition. Communities were selected by the Community Markets for Conservation based on evaluating the community's needs, intervention area, and resource availability. The repeated cross-sectional study design was used to collect data in four times points of the dry and rainy season of the year. Questionnaires were given to every household that was enrolled in the study which consisted of questions about anthropometric measures for both the child and the mother. Some of the factors considered in the study were the household egg acquisition, children's egg consumption, and children's egg consumption. Although egg production had decreased near the end of the intervention within the egg production centers, there was still a heightened consumption of eggs by younger children within the communities. The implementation of egg production centers did increase the odds that a child would eat an egg, however, produced the same frequency of egg consumption to those communities that were not involved in the program. Unlike interventions that focused entirely on village chickens which experienced greater chicken loss to disease and poor management, the egg production models alleviated these burdens and targeted low-income communities in rural environments. Some of the limitations within the study include the difficulty centers were having to keep up with demand due to the lack of production from the hens and the inability to perform a cluster randomized control trial because of the lack of resource availability.

Ferrari, P. (2017, March). Making animal-source foods more affordable. *Nurturing development: Improving human nutrition with animal-source foods*. Symposium conducted at the University of Florida, Gainesville, FL.

Link: [Ferrari](#)

The speaker illustrates how growth in agriculture is twice as effective at reducing poverty than growth in non-agricultural sectors. For efforts to be effective, components of trainings need to be diverse. The development model of Heifer International is presented to provide an example to the previous point; the model incorporates training in animal husbandry, natural resource management, leadership skills, and gender equity. The organization works to strengthen social, economic, and ecological influences in the communities. It provides emphasis on sustainable livestock development through access to animal health services and disease control and improved management, nutrition, and marketing of livestock and livestock products. The pathways in which the projects work is by donating livestock and giving training; building value chains pertaining to animal-source foods that involve developing markets and local economies; and focusing on social capital. To emphasize the third pathway, an example of a social network analysis conducted in Malawi after a Heifer project found that for every, one household engaged, five others were impacted.

Haddad, L. (2013). From Nutrition Plus to Nutrition Driven: How to realize the elusive potential of agriculture for nutrition. *Food and nutrition bulletin*, 34(1), 39-44.

Link: <https://doi.org/10.1177%2F156482651303400105>

The author offers evidence as to how nutrition is not being realized in agriculture programs and approaches to making nutrition a priority in agricultural programs. The pathways between agriculture and nutrition are outlined: greater farm productivity produces more income and income growth can improve nutrition status, although not seen consistently in the literature; food prices can decrease as supply increases which allows the prices of food with key micronutrients to decrease as well; more production can lead to more internal household consumption as well as general consumption outside of the home; and empowering women allows them to have greater control in the value chain which will reflect their priorities of enhancing nutrition for their families. The paper provides evidence that impact evaluations rarely measure nutrition or health impacts. Furthermore, data on the impact of agricultural growth on income or nutrition are not conclusive. The author offers possible solutions as the importance of mapping nutrition outcomes in real time; emphasizing the importance of impacts framed within the Millennium Development Goals; developing tools to identify points of leverage of agriculture on nutrition; creating indicators to measure nutrition; and developing appropriate building nutrition-agriculture leaders.

Haggblade, S., Duodu, K.G., Kabasa, J.D., Minnaar, A., Ojijo, N.K.O., Taylor, J.R.N. (2016). Emerging Early Actions to Bend the Curve in Sub-Saharan Africa's Nutrition Transition. *Food and Nutrition Policy*. 37(2): 219-241.

Link: <https://doi.org/10.1177%2F0379572116637723>

This article is a discussion paper that examines the state of nutrition transition in sub-Saharan Africa, and the heterogeneity in outcomes across the regions, countries, and households. It also aims to articulate the current emerging responses that center on protecting consumer health in three African countries that are at different stages/levels (obesity to child stunting; South Africa—advanced, Ghana—intermediate, and Uganda—early) of the agriculture-food system transition. Ultimately, it concludes with the emerging actions that may help to moderate the negative public health consequences of Africa's agriculture-food system transformation. Data included in this article is secondary data from the WHO, FAO, localized survey efforts as well as subject matter reviews by Africanist researchers. The authors used a classification system developed by Kaneene et al. using two principal indicators that drive food system transformation (i.e. urbanization and per capita income).

Results of the paper indicate that rapid urbanization and diet change are already leading to overweight problems in South Africa. However, in South Africa there is more action to combat this problem through public health programs, education and regulations. In Ghana and Uganda (as well as other African countries in the early and middle transitions) are not focusing on the obesity problem, but instead, the limited resources on undernutrition programs. Two categories of intervention appear to be feasible including maternal and child health programs addressing short-term undernutrition problems and reduce future tendency for overweight, as well as regulatory and fiscal actions that limit access to unhealthy foods, tax unhealthy foods or subsidize healthy foods. A third intervention including modernization of the agriculture-food system is also necessary. This includes improving programs for job skills training, marketing reforms and investing in small owner food industry jobs.

Miller, L. C., Joshi, N., Lohani, M., Rogers, B., Loraditch, M., Houser, R., ... and Mahato, S. (2014) Community development and livestock promotion in rural Nepal: Effects on child growth and health. *Food and Nutrition Bulletin*, 35(3), 312-326.

Link: <https://doi.org/10.1177%2F156482651403500304>

This study is an evaluation of the project described in the above reference of Darrouzet-Nardi et al. (2016). The study was a 24-month longitudinal, randomized, controlled trial. The Chitwan and Nawalparasi are considered 'the Terai region' throughout the paper and the Nuwakot is referred to as 'the hills'. The primary outcome of this study was child growth using the measures of weight, head, head circumference, and mid-upper-arm circumference. These were then converted into z-scores for height-for-age, weight-for-age, and weight-for-height; measures were then used to determine underweight, stunting, and wasting. A secondary outcome of the study was morbidity related to fever, diarrhea, or respiratory symptoms. Data was collected by questionnaires given when the researchers visited the households. There were 201 intervention households and 214 controls. There were 122 families enrolled from Chitwan, 150 in Nawalparasi, and 143 from Nuwakot. In the Terai intervention group the increase in socioeconomic status was nearly double over the control group; the hills region did not see any changes. For income, households in the Terai region showed an increase in income while the households in the hills did not. Land ownership did not differ between the intervention and control groups of the Terai and hills regions. For children between 6-60 months of age, improvement of HAZ and WAZ was significantly higher in the intervention group than the controls in both regions. Longer time spent with the Heifer program was associated with better HAZ. Frequency of illnesses did not differ over time for either region. Those in the intervention group from the Terai region were more likely to increase household sanitary practices and use iodized salt; the hills region did not see these changes in the intervention group.

Miller, L. C., Neupane, S., Joshi, N., Lohani, M., Rogers, B. L., Neupane, S., ... and Webb, P. (2019). Multisectoral community development in Nepal has greater effects on child growth and diet than nutrition education alone. *Public health nutrition*, 1-16.

Link: <https://doi.org/10.1017/S136898001900260X>

This study which was based in Nepal assessed the impact of child diet and growth of a multisectoral community intervention compared to nutrition education and livestock management training alone. The study performed a longitudinal community-based randomized trial that incorporated three villages. Each village received three different things 1) Full package community development activities, delivered via women's groups; 2) livestock training and nutrition education alone (partial package); or 3) no intervention (serving as the control). There were 974 household surveys with 1333 children aged 1-60 months old were collected and placed into a mixed-effect linear regression and Poisson model. Some of the factors included in the study were anthropometric measures, diet quality, diet diversity, and ASF. The results indicated that children who lived in villages that received full packages had better scores all around after adjusting for household and child-specific characteristics. Improvements were significant in household wealth and hygiene habits for the full package village compared to the partial

package and the control village. The multisectoral group showed had greatest success and identified that livestock management and nutrition and nutrition education alone had minute outcomes. A limitation within the study included the unexplainable differences in the outcomes of the three villages that were being studied. Another limitation of the study was the inclusion of the collinearity of independent variables within the data.

Mohammed, H., and Aboud, F. (2019). Adaptation of a mental development assessment tool for the evaluation of the long-term effect of a successful nutrition intervention in Ghana. *Maternal and child nutrition*, e12829.

Link: <https://doi.org/10.1111/mcn.12829>

This study adapted a cognitive assessment tool to evaluate nutritional programs and studied its reliability in Ghana. It assessed the long-term effects of the Enhancing Child Nutrition Through Animal Source Food Management Project (ENAM). The children of formal participants of the ENAM project were contacted and a cross-sectional data collection was used on the participants. Factors such as socioeconomic status, food insecurity, child intellectual function, dietary intake, school attendance, anthropometry, and symptoms of depression were included in the study. There was no change in intellectual functioning among those children who were in the intervention. The children did not show an improvement in their school performance. Although there was no clear indication of change with mental function, there was a clear indication that children within the program had a higher BMI, weight-for-age, and height-for-age z score compared to those students who had not been in the intervention within the span of 16 weeks. The study concludes that while enhancing nutrition does not make a significant impact to long term intellectual function, stimulation programs that are maintained on top of nutritional programs could improve mental development and that the adaption of the tool within Ghana was able to successfully evaluate the intellectual functioning of the adolescent. A limitation within the study was that the Wechsler Abbreviated Scale of Intelligence used within the study was not standardized for Ghana.

Murendo, C., Nhau, B., Mazvimavi, K., Khanye, T., and Gwara, S. (2018). Nutrition education, farm production diversity, and commercialization on household and individual dietary diversity in Zimbabwe. *Food and nutrition research*, 62.

Link: <https://doi.org/10.29219/fnr.v62.1276>

In this study, nutrition education, farm production diversity, and commercialization on household, and the dietary diversity of women and children were combined to be assessed jointly. Individual agricultural practices on dietary diversity and the roles of crop and livestock diversity were also analyzed but were investigated as separate roles. The cross-sectional study incorporated 2,815 randomly selected households drawn from the Crop and Livestock Production Survey. From the data, the study went ahead and randomly selected 36 households in each of the 10 wards in every district that covered eight different regions of Zimbabwe. Surveys were collected by 24-hour recall and estimated through a regression model. Factors considered in the study are commercialization, household dietary diversity, farm production diversity, nutrition education, and the dietary diversity of women and children. The study indicated that 80% of the sampled households received information on nutrition, child feeding, and care practices and on average 50% of households were engaged in crop or livestock sale. Overall, nutritional knowledge did lead to improvements in the dietary diversity of households, women, and children. There was also a strong positive association between farm production diversity and the dietary diversity of the household and women. Finally, market participation was shown to be positively associated with both the dietary diversity of women and children. Some of the limitations include the inability to incorporate seasonality of diets, the quantity of food consumption, and the bias which comes with using recall data.

Nordhagen, S., and Klemm, R. (2018). Implementing small-scale poultry-for-nutrition projects: Successes and lessons learned. *Maternal and child nutrition*, 14, e12676.

Link: <https://doi.org/10.1111/mcn.12676>

In this study, a consecutive cross-sectional survey was distributed to examine the Helen Keller International model for nutritional-sensitive poultry production. To assess the model the study incorporates a program that has been used in four diverse African locations, three of which were rural and one which was urban. Surveys were conducted with teams using tablet-based questionnaire that included open-ended questions. Enumerators were also tasked to observe the house to identify chicken coop or feeding tray. Some of the factors within the study included poultry rearing, nutritional practices, mortality of chickens, and egg usage. The study found that only a few households built improved henhouses and that poultry mortality was high throughout. The number of vaccinated individuals varied from household but was highest when support was provided to the family. While consumption of eggs was low, mothers who were more informed through the project were found to more likely eat eggs. Furthermore, the study indicates that a change in behavior requires strong communication from interventions and that programs focused on building nutrition through poultry should press more for improved practices rather than improved breeds. It is also highlighted that directly supporting women's ownership and decision making is necessary to empower women in chicken production.

Rawlins et al. (2014). Got milk? The impact of Heifer International's livestock donation programs in Rwanda on nutritional outcomes. *Food Policy*. 44: 202–213.

Link: <https://doi.org/10.1016/j.foodpol.2013.12.003>

This paper evaluates the favorable impacts of Heifer International's dairy cow and meat goat donation programs in Rwanda. The results indicated that the program substantially increased dairy and meat consumption and diverse diet among Rwandan households who were given a dairy cow or a meat goat. Households that received a dairy cow nearly triple increased the dairy consumption compared to control households. In addition, the households that received a goat nearly doubled the meat intake compared to controls. Moreover, there were statistically significant increases in weight-for-height z-scores and weight-for-age z-scores of about 0.4 SD among children aged 0–5 years in households that were recipients of meat goats, and increases in HFA z-scores of about 0.5 SD among children in households that received dairy cows.

Ruel, M., Alderman, H., and the Maternal Child Nutrition Study Group. (2013). Nutrition-sensitive interventions and programmes: how can they help accelerate progress in improving maternal and child nutrition? *Lancet*, 382(9891), 536-551.

Link: [https://doi.org/10.1016/S0140-6736\(13\)60843-0](https://doi.org/10.1016/S0140-6736(13)60843-0)

The paper reviews program from different sectors to examine the nutritional effect and ways these programs could become more nutrition-sensitive. The sectors addressed in the paper include those of agriculture, social safety nets, early childhood development, and schooling. Regarding the agriculture sector, it is mentioned that efforts at boosting food supply may not solve the issue of access and availability to nutritious and diverse diets poor people face. An emphasis should be put on making agricultural systems and food and agriculture policies more nutrition-sensitive should be undergone. The authors present enhancing household income of the poor and increasing access to high-quality diets can complement efforts to address the issue. Pathways in which agricultural programs can affect nutrition all point that women are key mediators and factors such as their social status, empowerment, control over resources, time allocation, and health and nutritional status are important when addressing agriculture inputs, intra-household allocation, and child nutrition. Homestead food production systems have been reviewed and an argument of these is there is little evidence of effectiveness of these programs on maternal or child nutritional status. Another finding after review of these types of studies

was the nutritional effect is more likely when interventions focus on women by conducting women's empowerment activities such as improving their knowledge and skills through behavior change communications or promoting their increased control over income; studies have not compared targeting men and women specifically, however. A third finding is sample sizes are usually too small and evaluations have been too poor to draw significant conclusions. The article highlights how even though women are targeted in messaging and programming, few studies have measured women's empowerment as a pathway to improved nutrition. The authors recommend including measures such as the effect of interventions on women's time, knowledge, practices, health, or nutritional status and modelling the mediating role of maternal resources on child nutrition. The agriculture section of the paper also highlights the use of biofortification.

Thevasagayam, S. (2017, March). Improving access to animal-source foods. *Nurturing development: Improving human nutrition with animal-source foods*. Symposium conducted at the University of Florida, Gainesville, FL.
Link: [Thevasagayam](#)

The speaker presents the private sector as being crucial to sustainably improving availability, access, and affordability to animal-source foods. The Nigeria Dairy Development Program is used as an example of women being empowered to increase productivity and income which will lead to better nutritional outcomes. Components of the project include increasing income through a guaranteed market; being led by women which leads to better control, decision making, and income; increasing volume of dairy products produced which creates more products available on the market; and improved food safety to improve animal health, husbandry, and technical support. The Ethiochicken project has similar components in addition to behavior change interventions to change attitudes and behaviors towards animal-source foods consumption. A recent review of research identified gaps in the areas of fresh food value chains, animal-source food value chains, seasonality, post-harvest, food safety, prices and affordability of nutritious diets, behavior change communication, policy, and targeting adolescents.

Van Zanten, H. H., Herrero, M., Van Hal, O., Rööß, E., Muller, A., Garnett, T., ... and De Boer, I. J. (2018). Defining a land boundary for sustainable livestock consumption. *Global change biology*, 24(9), 4185-4194.
Link: <https://doi.org/10.1111/gcb.14321>

This study investigates how livestock could be fed with low-opportunity cost feedstuff to the food supply, all while decreasing land use. A demonstration of how the use of a circular economy to raise livestock is used to conceptualize how this intervention could provide people with enough of their daily protein needs. Some of the factors included in the study are the environmental impacts of eating ASF from low-cost livestock and the role of livestock characteristics on the utilization of leftovers. The study distances themselves from the term “reducing footprints” and instead argues that the focus should be on improving life-time herd productivity which would allow for human-edible feed in the diets of livestock. Although results indicate that low-cost livestock can support the daily protein needs of the world, this varies across region and is also constantly changing. A great need that is emphasized within the study is that it is essential to reduce the consumption of ASF in the Americas, Europe, and Oceania. While reduction is crucial, a vegan diet creates the best use of land compared to other food consumption methods. Although a range of ASF could be made if livestock is fed low-opportunity cost feedstuff, some products like beef and milk will rise in methane. Even at this rise, the study concludes that using this consumption pathway could reduce emissions significantly compared to the “business as usual scenario.” It is also emphasized that this method requires heightened collaborations between governments and private institutions to manage, resource, education, and policies to meet sustainable needs.

Additional Resources:

- Homiah, P. A., Sakyi-Dawson, O., Bonsu, A. M., and Marquis, G. S. (2012). Microenterprise development coupled with nutrition education can help increase caregivers' incomes and household accessibility to animal source foods. *African Journal of Food, Agriculture, Nutrition and Development*, 12(1), 5725-5745.
- Nikiéma, L., Huybregts, L., Martin-Prevel, Y., Donnen, P., Lanou, H., Grosemans, J., ... and Kolsteren, P. (2017). Effectiveness of facility-based personalized maternal nutrition counseling in improving child growth and morbidity up to 18 months: A cluster-randomized controlled trial in rural Burkina Faso. *PLOS ONE*, 12(5), e0177839.
- World Health Organization. (2017). Double-duty actions for nutrition: policy brief.

Animal Source Food Supply Chain

- Abdulai, A., and Birachi, E. A. (2009). Choice of coordination mechanism in the kenyan fresh milk supply chain. *Review of Agricultural Economics*, 31(1), 103–121.
Link: <https://doi.org/10.1111/j.1467-9353.2008.01428.x>

Abdulai et al. examine the nature and determinants of coordination mechanisms used in the Kenyan fresh milk supply chains. This paper used surveys to obtain data on milk transactions from dairy farmers and intermediaries in Nakuru and Nyandarua districts in Kenya. In this analysis the authors considered gender, education, experience, quality, transport, and transactional costs. Price information, time required to sell milk, and distance between producers and buyers are some of the most significant transaction costs that influence coordination between buyer and producers. Interventions are needed in order to improve the level of coordination in the supply chain, both physical and economic infrastructure should be improved, this infrastructure includes, but is not limited to: roads, transports and communication technologies.

- Bello, M., Lawan, M. K., Aluwong, T., and Sanusi, M. (2015). Management of slaughter houses in northern Nigeria and the safety of meat produced for human consumption. *Food Control*, 49, 34–39.
Link: <https://doi.org/10.1016/j.foodcont.2013.09.007>

Bello et al. analyze management of major slaughterhouses in northern Nigeria to assess the safety of the meat produced for public consumption. On-the-spot assessments of the operational facilities and focus group discussions were used as data collection methods. The factors considered in the study were: date of establishment, infrastructure, operations, diseases, and sanitation. The conclusion in this article is that meat production does not meet safety standards and very poor sanitation practices. This poses a challenge to achieve sustainable food security in Nigeria. There are various possible solutions to these problems, but they rely heavily on policy interventions.

- Emam, A. A., and Hassan, A. M. (2011). Measuring Profitability and Viability of Poultry Meat Production in Khartoum, *Australian Journal of Basic and Applied Sciences* 5(7), 937–941.
Link: http://www.sustech.edu/staff_publications/2011092106393525.pdf

In this paper, Abdalla et al studies the economics of poultry production in Khartoum State, Sudan. Stratification of farms for questionnaires was used as a primary source of data collection. Information from other sources was gathered as secondary data. Quantitative analysis of this information was used to obtain economic indicators for analysis. Some of the factors considered by the author were: farm size, level of education, experience and age. The author concludes that larger farms are more efficient

and that there is evidence suggesting they have better disease management than smaller farms. Feed for the animals is the main cost for all type of farming enterprises (large or small).

- Mlote, S. N., Mdoe, N. S. Y., Isinika, A., and Mtenga, L. A. (2012). Value addition of beef cattle fattening in the lake zone in Tanzania: Challenges and opportunities. *Livestock Research for Rural Development*, 24(6), 2.**

Link: <http://www.lrrd.cipav.org.co/lrrd24/6/mlot24095.htm>

This study analyses value addition in the different stages of the supply chain of beef in Tanzania to determine challenges and opportunities. The method for collection of primary data were: focus groups and structured questionnaires with stakeholders (Pastoralists / Agro-pastoralists, Beef cattle fattening operators, traders, processors, butcheries and government officials). The main factor considered in this study is value addition in each part of the supply chain, in order to identify possible improvement opportunities. The conclusion reached by the authors is that the supply chain is underdeveloped having especially low value addition from pastoralists and high value addition from beef cattle fatteners. It shows that there are still serious challenges such as high prices of fattening feeds, limited availability of credits to expand fattening enterprises, no designated area for conducting fattening, unreliable supply of feed stuff, lack of improved fattening skills/education, poor linkages and low collaboration among and between the actors in the chain. A series of recommendations such as increased collaboration, capacity building, and policy changes are mentioned as possible solutions increase value addition in the beef supply chain.

- Nakiganda, A., Mcleod, A., Bua, A., Phipps, R., Upton, M., and Taylor, N. (2006). Farmers' constraints, objectives and achievements in smallholder dairy systems in Uganda. *Livestock Research for Rural Development*, 18(5), 1–7.**

Link: <http://www.lrrd.cipav.org.co/lrrd18/5/naki18069.htm>

Nakiganda et al. analyze constraints, objectives and achievements in dairy production of smallholder farmers in Uganda. This study did a cross-sectional survey and a longitudinal study using participatory methods (focus groups, individual semi-structured interviews, farmer data recording, participatory budgeting, objective matrix, ranking and scoring, and resource flow maps. Some of the factors considered were: transaction costs, cattle inputs, household problems, weather, income, and pest and disease management. The study draws to the conclusion that farmers who rely in milk production to cover school fees are more susceptible to be unable to meet school fees. The major constraints in smallholder milk production are: drought, poor milk market, low milk prices, failure to sell milk, and lack of transportation to markets.

- Ogola, T. D. O. ., Nguyo, W. K. ., and Kosgey, I. S. . (2010). Dairy goat production practices in Kenya: Implications for a breeding programme. *Livestock Research for Rural Development*, 22(1), 1–14.**

Link: <https://lrrd.cipav.org.co/lrrd22/1/ogol22016.htm>

This paper analyzes smallholder goat dairy production in Kenya to analyze and determine key aspects to make the farming of goats sustainable. Personal interviews and structured questionnaires were used to gather the data. Factors taken into consideration in this study were: household characteristics, education, occupation, land size, experience, etc. Constraints found in goat production were more tied to insufficient resources (land, feed, financial) and the external market rather than to lack of knowledge from the livestock owner. The development of crossbreds between local and exotic goats may be a solution to the prevailing environmental, nutritional, production and management constraints.

- Ugwu, D. S. (2010). Dairy Production among Small and Medium Scale Farmers in Nigeria: A Case Study of Kaduna and Kano States, 6(1), 1–6.**

Link: <https://pdfs.semanticscholar.org/5e24/2e06329cd842a6b35c954a68ea3d10ee0ac9.pdf>

Ugwu studies dairy production and processing among small and medium scale farmers in Kaduna and Kano states (Nigeria). Ugwu used focus group discussions, consultation meetings, and in-depth interviews with various stakeholders involved in the dairy production in Kaduna and Kano in order to collect the data. Some of the factors considered by Ugwu were: Production system (pastoralist, agro pastoralist, mixed farming etc.), processing and marketing, characteristics of production (yield/breed), and constraints. The conclusions from this study are that there is a need of improvement in: provision of technical and business advisory services, market development, capacity building, technologies, and institutional and infrastructural support. The implementation of these recommendations would foster growth in the dairy sub-sector.

Wambui, J. M. (2016). Design of Trucks for Long Distance Transportation of Cattle in Kenya and its Effects on Cattle Deaths. *African Journal of Food, Agriculture, Nutrition and Development*, 16(4), 1–15.

Link: <http://www.bioline.org.br/abstract?nd16054>

In this article the author makes emphasis in the importance of transportation in the meat value chain in Kenya and argues that truck design has a direct impact on the number of animals that die during transportation. The methods used for data collection were questionnaires to truckers in charge of transporting livestock from producers to slaughterhouses. Factors considered in the study were: truck design and demographic characteristics. Although trucks with poor design were had the higher number of deaths of livestock during transportation, there was no statistical significance to link truck design with livestock survival during transportation. The reason for this is that none of the trucks (even the ones categorized as good design) are dedicated to transport livestock, they are just adapted. Present design of trucks is not sufficient to guarantee animal welfare. The results reflect that there is poor handling along all the value chain and further studies are needed to understand undesired livestock death along the value chain.

Additional Resources identified between April 2018 and October 2019

Bartter, J., Diffey, H., Yeung, Y. H., O'Leary, F., Häslér, B., Maulaga, W., and Alders, R. (2018). Use of chicken eggshell to improve dietary calcium intake in rural sub-Saharan Africa. *Maternal and child nutrition*, 14, e12649.

Link: <https://doi.org/10.1111/mcn.12649>

Bekelman, T. A., Santamaría-Ulloa, C., and Dufour, D. L. (2019). Variation in dietary intake and body fatness by socioeconomic status among women in the context of Costa Rican nutrition transitions. *Journal of Biosocial Science*, 1-18.

Link: <https://doi.org/10.1017/S0021932019000403>

De Bruyn, J., Thomson, P. C., Darnton-Hill, I., Bagnol, B., Maulaga, W., and Alders, R. G. (2018). Does village chicken-keeping contribute to young children's diets and growth? A longitudinal observational study in rural Tanzania. *Nutrients*, 10(11), 1799.

Link: <https://doi.org/10.3390/nu10111799>

Choudhury, S., and Headey, D. D. (2018). Household dairy production and child growth: Evidence from Bangladesh. *Economics and Human Biology*, 30, 150-161.

Link: <https://doi.org/10.1016/j.ehb.2018.07.001>

- Christian, A. K., Wilson, M. L., Aryeetey, R. N., and Jones, A. D. (2019). Livestock ownership, household food security and childhood anaemia in rural Ghana. *PLOS ONE*, 14(7), e0219310.
Link: <https://dx.doi.org/10.1371/journal.pone.0219310>
- Dumas, S. E., Lewis, D., and Travis, A. J. (2018). Small-scale egg production centres increase children's egg consumption in rural Zambia. *Maternal and child nutrition*, 14, e12662.
Link: <https://doi.org/10.1111/mcn.12662>
- Eaton, J. C., Rothpletz-Puglia, P., Dreker, M. R., Iannotti, L., Lutter, C., Kaganda, J., and Rayco-Solon, P. (2019). Effectiveness of provision of animal-source foods for supporting optimal growth and development in children 6 to 59 months of age. *Cochrane Database of Systematic Reviews*, (2).
Link: <https://doi.org/10.1002/14651858.CD012818.pub2>
- Fadare, O., Mavrotas, G., Akerele, D., and Oyeyemi, M. (2019). Micronutrient-rich food consumption, intra-household food allocation and child stunting in rural Nigeria. *Public health nutrition*, 22(3), 444-454.
Link: <https://doi.org/10.1017/S1368980018003075>
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Link: <https://doi.org/10.1111/mcn.12818>
- Jones, A. D., Colecraft, E. K., Awuah, R. B., Boatemaa, S., Lambrecht, N. J., Adjorlolo, L. K., and Wilson, M. L. (2018). Livestock ownership is associated with higher odds of anaemia among preschool-aged children, but not women of reproductive age in Ghana. *Maternal and child nutrition*, 14(3), e12604.
Link: <https://doi.org/10.1111/mcn.12604>
- Kaimila, Y., Divala, O., Agapova, S. E., Stephenson, K. B., Thakwalakwa, C., Trehan, I., ... and Maleta, K. M. (2019). Consumption of animal-source protein is associated with improved height-for-age z scores in rural Malawian children aged 12–36 months. *Nutrients*, 11(2), 480.
Link: <https://doi.org/10.3390/nu11020480>
- Kim, S. S., Nguyen, P. H., Tran, L. M., Abebe, Y., Asrat, Y., Tharaney, M., and Menon, P. (2019). Maternal behavioural determinants and livestock ownership are associated with animal source food consumption among young children during fasting in rural Ethiopia. *Maternal and child nutrition*, 15(2), e12695.
Link: <https://doi.org/10.1111/mcn.12695>
- Lambrecht, N. J., Wilson, M. L., and Jones, A. D. (2019). Assessing the Impact of Animal Husbandry and Capture on Anemia among Women and Children in Low-and Middle-Income Countries: A Systematic Review. *Advances in Nutrition*, 10(2), 331-344.
Link: <https://doi.org/10.1093/advances/nmy080>
- Li, M., Havelaar, A. H., Hoffmann, S., Hald, T., Kirk, M. D., Torgerson, P. R., and Devleeschauwer, B. (2019). Global disease burden of pathogens in animal source foods, 2010. *PLOS ONE*, 14(6), e0216545.
Link: <https://doi.org/10.1371/journal.pone.0216545>
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Link: <https://doi.org/10.1111/mcn.12678>

- Marinda, P. A., Genschick, S., Khayeka-Wandabwa, C., Kiwanuka-Lubinda, R., and Thilsted, S. H. (2018). Dietary diversity determinants and contribution of fish to maternal and under-five nutritional status in Zambia. *PLOS ONE*, 13(9), e0204009.
Link: <https://doi.org/10.1371/journal.pone.0204009>
- Miller, L. C., Neupane, S., Joshi, N., Lohani, M., Rogers, B. L., Neupane, S., ... and Webb, P. (2019). Multisectoral community development in Nepal has greater effects on child growth and diet than nutrition education alone. *Public health nutrition*, 1-16.
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Link: <https://doi.org/10.4269/ajtmh.18-0333>
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Link: <https://doi.org/10.1111/mcn.12676>
- Pimpin, L., Kranz, S., Liu, E., Shulkin, M., Karageorgou, D., Miller, V., ... and Mozaffarian, D. (2019). Effects of animal protein supplementation of mothers, preterm infants, and term infants on growth outcomes in childhood: a systematic review and meta-analysis of randomized trials. *The American journal of clinical nutrition*.
Link: <https://doi.org/10.1093/ajcn/nqy348>
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Link: <https://doi.org/10.1371/journal.pone.0200235>
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Link: <https://doi.org/10.1093/advances/nmz018>
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