Nutritional value of animal source foods

Crafting USAID’s Livestock Research Agenda
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1) Undernutrition in vulnerable groups
   1) Global burden, consequences, and vulnerable groups
   2) Bioavailability of critical micronutrients (vitamins A, B\textsubscript{12}, iron, and zinc) in animal source foods (ASF)

2) Research at the intersection of nutrition & livestock development
   1) Pastoralist milk nutrition – Samburu, Kenya
   2) Egg nutrition – Pastocalle, Ecuador

3) Potential research agenda
Why undernutrition?

45% child deaths due to undernutrition

WHO 2011
Global burden of disease

Nutrition Risk Factors

- Stunting
- Severe wasting
- IUGR
- Sub-optimal breastfeeding
- Vitamin A deficiencies
- Zinc deficiencies

Global Health Burden

- 3.1 million (45%) of deaths to children <5 yr (2013)
- 140.5 million (35%) of DALYs for children < 5 yr and 10% of global DALYs (2008)

Black et al. Lancet 2013
Worldwide timing of growth faltering

**FIGURE 1**
Mean anthropometric z scores according to age for all 54 studies, relative to the WHO standard (1 to 59 months).

Victora et al. Shrimpton Pediatrics 2010
Global prevalence of stunting

Black et al. 2008
Vulnerable groups

- Pregnant and lactating women
- Children less than 5 years
- School-age children
The Biology of Nutrition

1) INTAKE
2) ABSORPTION
3) TRANSPORT
4) METABOLISM
5) STORAGE
6) ELIMINATION
Essential Nutrients

• Constituents in the diet required for growth, health, and survival - not endogenously produced in sufficient levels

  – Macronutrients – protein/amino acids, carbohydrates, lipids/fatty acids, fiber

  – Micronutrients
    • Vitamins (organic) – A (β-carotene, retinol), B (thiamin), riboflavin, niacin, pyridoxine, cobalamin, pantothenic acid, folate), C (ascorbic acid), D (calciferol), E (α-tocopherol), K, choline

    • Minerals/elements/trace minerals (inorganic) – calcium, iron, zinc, iodine, selenium, copper, fluoride, phosphorus, magnesium, manganese

  – Water & electrolytes – sodium, chloride, potassium, inorganic sulfate
Vitamin A

• Physiology
  – Vision: retinal *opsin* → *rhodopsin*
  – Immunity: epithelial tissue, adaptive
  – Gene expression: reproductive health, cellular differentiation, embryogenesis, etc.

• Deficiency
  – Leading cause of preventable blindness globally
  – 250 million preschool age children have VAD

• Dietary sources
  – Preformed retinol – liver, meats, fish, eggs, and milk
  – Proformed retinoids - dark green, yellow, and orange fruits and vegetables
  – 1 RE = 1μg retinol = 12 μg β-carotene = 24 μg carotenoid
Vitamin B$_{12}$ (cobalamin)

• Physiology
  – Synthesized by anaerobic bacteria in ileal, after duodenum
  – Cobalamin needed to synthesize succinyl CoA and methionine

• Deficiency
  – megaloblastic anemia
  – neurological disease (demyelination and peripheral neuropathy); impaired brain development

• Dietary sources
  – No plants except algae
  – Meat, poultry, fish, eggs, milk, and fortified foods
Iron

- **Physiology**
  - Oxidation-reduction reactions
  - Oxygen transport, enzyme activity in cellular respiration, division, neurotransmission, immunity, and growth

- **Deficiency**
  - 115,000 maternal deaths; 18% of children < 5 yrs
  - 3.4 million DALYs attributable to IDA

- **Dietary sources**
  - Heme iron (20-50% absorbed): meat, poultry; Non-heme (0.1-35% absorbed): fruits, vegetables, grain
  - Enhancers: meat, vitamin C; Inhibitors: phytates and polyphenols
Zinc

• **Physiology**
  – Zn > 300 enzymes structural & regulatory roles
  – Protein and nucleic acid synthesis
  – Growth & immune functioning

• **Deficiency**
  – 30% of children < 5yrs stunted
  – 17.3% of world’s population inadequate zinc intake

• **Dietary sources**
  – Fish, shellfish meats, whole grains, nuts, and legumes
  – Enhancers: protein-rich foods/meat; Inhibitors: phytates in maize, legumes, oxylates
Evolutionary Discordance

- **Homo erectus**: 2 million - 15,000 years ago
  - Stature & body weight increased as moved to hunter-gathering
  - Nomadic existence: 15% taller & healthier (Walker 1993)

- **Paleolithic nutrition**: (Konner & Eaton *NEJM* 1985)
  - Discordance theory: human genome evolve to adapt to conditions that no longer exist. Mismatch is causing chronic diseases
Paleolithic nutrition: key differences

- **Energy** ↑ - due to physical demands
- Carbohydrates (45-50%, similar) – different types, many varieties of fruit & vegetables, rarely grains, and no refined sugar
- **Protein** ↑ (30% of energy) - marine (ocean), lacustrine (lake), and riverine (river) species, meat
- **Fatty acids** – different types lean game meat, fish/shell foods, n-6:n-3=1; DHA↑
- **Micronutrients** ↑ – many varieties and high levels of fruits, nuts, legumes exceed today’s DRIs
- **Potassium (K⁺):Sodium (Na⁺)** >5 in HG; (alkaline in HG rather than acidic) now Na⁺ > K⁺
- **Fiber** ↑ (>100 g/d compared to 20 g/d) - other phytochemicals, flavonoids, plant phenols
Research at the intersection of

NUTRITION & LIVESTOCK
Nutrition-sensitive approaches

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**Benefits during the life course**
- Morbidity and mortality in childhood
- Cognitive, motor, socioemotional development
- School performance and learning capacity
- Adult stature
- Obesity and NCDs
- Work capacity and productivity

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**Optimum fetal and child nutrition and development**
- Breastfeeding, nutrient-rich foods, and eating routine
- Feeding and caregiving practices, parenting, stimulation
- Low burden of infectious diseases
  - Food security, including availability, economic access, and use of food
  - Feeding and caregiving resources (maternal, household, and community levels)
  - Access to and use of health services, a safe and hygienic environment

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**Nutrition specific interventions and programmes**
- Adolescent health and preconception nutrition
- Maternal dietary supplementation
- Micronutrient supplementation or fortification
- Breastfeeding and complementary feeding
- Dietary supplementation for children
- Dietary diversification
- Feeding behaviours and stimulation
- Treatment of severe acute malnutrition
- Disease prevention and management
- Nutrition interventions in emergencies

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**Nutrition sensitive programmes and approaches**
- Agriculture and food security
- Social safety nets
- Early child development
- Maternal mental health
- Women’s empowerment
- Child protection
- Classroom education
- Water and sanitation
- Health and family planning services

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**Building an enabling environment**
- Rigorous evaluations
- Advocacy strategies
- Horizontal and vertical coordination
- Accountability, incentives regulation, legislation
- Leadership programmes
- Capacity investments
- Domestic resource mobilisation

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Black et al. Lancet 2013
Pastoralist milk nutrition - Samburu, Kenya
High levels of nutrient inadequacy

Iannotti and Lesorogol CA 2014
## Food source of nutrients

**Table 3. Food group source of nutrients (%), 2010**

<table>
<thead>
<tr>
<th></th>
<th>Energy</th>
<th>Vitamin A</th>
<th>Vitamin B&lt;sub&gt;12&lt;/sub&gt;</th>
<th>Vitamin C</th>
<th>Folate</th>
<th>Iron</th>
<th>Zinc</th>
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<tbody>
<tr>
<td>Maize</td>
<td>49</td>
<td>34</td>
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<td>27</td>
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<td>51</td>
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<tr>
<td>Rice</td>
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<td>0</td>
<td>0</td>
<td>7</td>
<td>5</td>
<td>13</td>
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<tr>
<td>Potatoes</td>
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<td>0</td>
<td>0</td>
<td>33</td>
<td>2</td>
<td>3</td>
<td>1</td>
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<tr>
<td>Beans</td>
<td>11</td>
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<td>0</td>
<td>0</td>
<td>57</td>
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<td>Meat</td>
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<td>6</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Milk</td>
<td>10</td>
<td>57</td>
<td>94</td>
<td>50</td>
<td>6</td>
<td>2</td>
<td>11</td>
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<td>Vegetables</td>
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<td>17</td>
<td>1</td>
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<td>0</td>
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<tr>
<td>Fat</td>
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<td>0</td>
<td>0</td>
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<tr>
<td>Sugar</td>
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<td>0</td>
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<td>0</td>
</tr>
</tbody>
</table>
Regression analyses & conclusions

• Cattle and chicken ownership increased dietary diversity (adj $R^2=.33$; $P<.001$)

• Livestock ownership increased nutrient adequacy for vitamin A, $B_{12}$, and zinc (adj $R^2=.06-.16$; $P<.001$)
  – Milk consumption increased BMI z scores among youth ($P<0.001$). (Iannotti and Lesorogol AJPA 2014)

• Support ongoing livestock production and milk consumption among pastoralist children
Egg nutrition – Pastocalle, Ecuador
Egg study – Pastocalle, Ecuador

- RCT to test effects of daily egg consumption among children 6-12 mo (n=180)

- Eggs purchased from local producers

- Outcomes: anthropometry, biomarkers of choline, vitamin B$_{12}$, lipids and amino acids
Potential nutrition & livestock

RESEARCH AGENDA
Research questions

• **Improve design and methods** of nutrition & livestock intervention studies

• Can low-cost, “renewable” ASF (eggs & milk) improve nutrition in vulnerable groups?
  - Are ASF more cost-effective for improving nutrition than fortified foods & supplements?

• Will poor households reserve eggs and milk for vulnerable groups, while selling others for livelihood?
  - What health and nutrition messages are needed?
  - Can hygienic practices with livestock production mitigate child diarrheal disease
Research questions

• What is the minimum ASF needed to sustain nutrition in vulnerable populations without crossing the threshold for increased chronic disease risk?
  – Micronutrients (vit A, D, E, choline iron) in ASF can be stored in body.

• Can we leverage the potential for synergistic effects on poverty reduction and improved nutrition from small livestock production?
  – School-based ASF interventions that support local economic development
  – Household level ASF intervention with young children