Impact of Micronutrient Fortification of Foods on Nutrition and Health Status: Fortified Complementary Feeding for the Prevention of Malnutrition

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Marjoleine Dijkhuizen (Copenhagen University); Jacques Berger (IRD); Pham Van Phu (Hanoi Medical University); Nanna Roos (Copenhagen University; Jutta Skau (Copenhagen University)
WHY ARE COMPLEMENTARY FOODS ‘SPECIAL’
Mean anthropometric z scores according to age for all 54 studies, relative to the WHO standard (1 to 59 months):

WORLDWIDE

Complementary food period


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Mean height for age z scores according to REGION

First 6 months are OK... then growth faltering

Complementary food period

Stunted


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Mean height for age z scores according to REGION

FIRST 6 MONTHS ARE OK.... THEN GROWTH FALTERING

By 2 years of age: HALF OF THE CHILDREN ARE STUNTED

STUNTED

WHAT IS STUNTING ??
THIS IS STUNTING:

Same class..... Same age (11 years) .... Different height
THIS IS STUNTING:

They are ALL stunted........She is OK..
**Effects of stunting....**

**Maternal and Child Nutrition 1**

Maternal and child undernutrition and overweight in low-income and middle-income countries


<table>
<thead>
<tr>
<th>Condition</th>
<th>Attributable deaths with UN prevalences*</th>
<th>Proportion of total deaths of children younger than 5 years</th>
<th>Attributable deaths with NIMS prevalences†</th>
<th>Proportion of total deaths of children younger than 5 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fetal growth restriction (&lt;1 month)</td>
<td>817 000</td>
<td>11.8%</td>
<td>817 000</td>
<td>11.8%</td>
</tr>
<tr>
<td>Stunting (1–59 months)</td>
<td>1 017 000*</td>
<td>14.7%</td>
<td>1 179 000†</td>
<td>17.0%</td>
</tr>
<tr>
<td>Underweight (1–59 months)</td>
<td>999 000*</td>
<td>14.4%</td>
<td>1 180 000†</td>
<td>17.0%</td>
</tr>
<tr>
<td>Wasting (1–59 months)</td>
<td>875 000*</td>
<td>12.6%</td>
<td>800 000†</td>
<td>11.5%</td>
</tr>
<tr>
<td>Severe wasting (1–59 months)</td>
<td>516 000*</td>
<td>7.4%</td>
<td>540 000†</td>
<td>7.8%</td>
</tr>
<tr>
<td>Zinc deficiency (12–59 months)</td>
<td>116 000</td>
<td>1.7%</td>
<td>116 000</td>
<td>1.7%</td>
</tr>
<tr>
<td>Vitamin A deficiency (6–59 months)</td>
<td>157 000</td>
<td>2.3%</td>
<td>157 000</td>
<td>2.3%</td>
</tr>
<tr>
<td>Suboptimum breastfeeding (0–23 months)</td>
<td>804 000</td>
<td>11.6%</td>
<td>804 000</td>
<td>11.6%</td>
</tr>
<tr>
<td>Joint effects of fetal growth</td>
<td>1 248 000</td>
<td>10.4%</td>
<td>1 248 000</td>
<td>10.4%</td>
</tr>
</tbody>
</table>

15 – 17% of all child deaths Associated with Stunting......
The special case of CFs

Maternal and Child Nutrition 1

Maternal and child undernutrition and overweight in low-income and middle-income countries


Almost all stunting takes place in the first 1000 days after conception. The few randomised controlled trials of breastfeeding promotion that included nutritional status outcomes did not show any effects on the weight or length of infants. By contrast, there is strong evidence that the promotion of appropriate complementary feeding practices reduces the incidence of stunting. A meta-analysis of zinc supplementation trials has shown a significant protective effect against stunting.
BUT.....
Complementary Food period is not the only important period....

The whole childhood should be taken into account....

Prentice, AJCN 2013
Baseline results FORISCA

STUNTING PROGRESSES WITH AGE......

Cambodian school children (n=2500) in Kompong Speu province.....
At 5 years ~45% stunted
At 12 years ~55% stunted
WHY THIS PATTERN OF GROWTH FALTERING IN ASIA

- No high-quality low-cost CF foods available?
  → leading to micronutrient deficiencies and deficiency of ‘type-2’ / growth nutrients?
  → leading to stunting?
- Low rates of continuing breast feeding?
- High prevalence of infection (diarrhea)?
Complementary foods and growth

Systematic review of the efficacy and effectiveness of complementary feeding interventions in developing countries

Kathryn G. Dewey and Seth Adu-Afarwuah
Program in International and Community Nutrition, University of California, Davis, California, USA
Can we prevent malnutrition / growth faltering / stunting in SE Asia ??

Randomized, controlled trial in Vietnam of fortified complementary foods
Production, Impact and Promotion of Micronutrient Fortified Complementary Foods in Vietnam

Jacques Berger¹, Nguyen Van Hoan²-³, Olivier Bruyeron³

¹ Institute of Research for Development (IRD)
UMR 204 NutriPAss, France

² National Institute of Nutrition, Vietnam

³ Group of Research and Technological Exchanges, France
Objective of the project

To promote **adequate feeding practices** of infants and young children with limited economic resources **to control stunting and micronutrient deficiencies**

Promotion of optimal breastfeeding and timely consumption of adequate **complementary foods (fortified)**
CFs made from local staple foods

<table>
<thead>
<tr>
<th>Rice flour</th>
<th>or</th>
<th>rice gruel +</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice (51%), soybean (21%), sesame (5%), sugar (15%), whole milk (5%), Ca₃(PO₄)₂ (1.2%), salt (0.7%)</td>
<td>Vitamin-Mineral (0.8%)</td>
<td>Soybean (87.67%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FG amylase (0.03%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ca₃(PO₄)₂ (6.1%), salt (3.1%), Vitamin-Mineral (3.1%)</td>
</tr>
</tbody>
</table>
TRIAL DESIGN: 29 VILLAGES RANDOMIZED

Registered (at 3.5 months) n=437

Included at baseline (5 months ± 7 days) n=426

FF n=157
- Anthropometry n=157
- Hb n=157
- PF n=157
- TfR n=157
- Retinol n=157
- Zinc n=157
- Excluded n=2
  - Abandon n=9
  - No end point n=11

FC n=135
- Anthropometry n=135
- Hb n=135
- PF n=134
- TfR n=135
- Retinol n=135
- Zinc n=135
- Excluded n=1
  - Abandon n=13
  - No end point n=7

C n=134
- Anthropometry n=134
- Hb n=134
- PF n=133
- TfR n=134
- Retinol n=131
- Zinc n=134
- No end point n=6

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TRIAL DESIGN : 29 VILLAGES RANDOMIZED

- In FF and FC villages: canteens were mothers could come with their infant to get free meal of porridge (on average 2 – 3 times per day)

- In control group: no intervention
Were micronutrient deficiencies prevalent in Vietnam?

<table>
<thead>
<tr>
<th>Micronutrient Deficiency</th>
<th>Baseline</th>
<th>Final</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anemia (Hb &lt; 110 g/L)</td>
<td>66.4 (58.4, 74.4)</td>
<td>56.1 (47.3, 64.9)</td>
<td>~60% anemia</td>
</tr>
<tr>
<td>Low ferritin (&lt; 12 μg/L)</td>
<td>27.8 (20.7, 36.0)</td>
<td>58.2 (49.0, 66.5)</td>
<td>~30 – 60% iron deficiency</td>
</tr>
<tr>
<td>High TfR (&gt; 8.5 mg/L)</td>
<td>2.2 (0.0, 4.7)</td>
<td>4.9 (1.1, 8.7)</td>
<td>~50% vitamin A deficiency</td>
</tr>
<tr>
<td>Low retinol (&lt; 0.70 μmol/L)</td>
<td>83.2 (77.7, 89.6)</td>
<td>45.5 (36.7, 54.3)</td>
<td>~50% zinc deficiency</td>
</tr>
<tr>
<td>Low zinc (&lt; 9.9 μmol/L)</td>
<td>67.2 (59.5, 74.9)</td>
<td>52.9 (44.3, 61.5)</td>
<td></td>
</tr>
<tr>
<td>ID (PF &lt; 12 μg/L or TFR &gt; 8.5 mg/L)</td>
<td>28.6 (20.9, 36.3)</td>
<td>57.5 (48.6, 66.4)</td>
<td></td>
</tr>
<tr>
<td>IDA</td>
<td>18.8 (12.1, 25.4)</td>
<td>37.5 (28.8, 46.2)</td>
<td></td>
</tr>
</tbody>
</table>

YES
WAS THERE AN EFFECT OF FORTIFIED COMPLEMENTARY FOODS ON MICRONUTRIENT STATUS?
EFFECT OF FORTIFIED COMPLEMENTARY FOODS ON MICRONUTRIENT STATUS.....

<table>
<thead>
<tr>
<th></th>
<th>FF</th>
<th></th>
<th></th>
<th>FC</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>%</td>
<td></td>
<td>n</td>
<td>%</td>
</tr>
<tr>
<td>Anemia (Hb &lt;110 g/L)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>157</td>
<td>62.4 (54.8, 70.0)</td>
<td></td>
<td>135</td>
<td>71.9 (64.2, 79.5)</td>
</tr>
<tr>
<td>Final</td>
<td>120</td>
<td>36.7 (28.0, 45.3)</td>
<td>106</td>
<td>28.3 (19.7, 36.9)</td>
<td></td>
</tr>
<tr>
<td>Low ferritin (&lt;12 μg/L)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>157</td>
<td>30.6 (23.4, 37.8)</td>
<td></td>
<td>134</td>
<td>20.9 (13.9, 27.6)</td>
</tr>
<tr>
<td>Final</td>
<td>120</td>
<td>14.2 (7.9, 20.4)</td>
<td>106</td>
<td>14.2 (7.5, 20.8)</td>
<td></td>
</tr>
<tr>
<td>High Tfr (&gt;8.5 mg/L)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| Baseline                       | 157| 3.2 (0.4, 5.9) |     | 134| 2.2 (0.0, 4.7) | 50% REDUCTION IN PREVALENCE OF MICRONUTRIENT DEFICIENCIES OVER 6 MONTH INTERVENTION
| Final                          | 120| 0.8 (0, 2.5) | 106| 1.9 (0.0, 4.5) |
| Low retinol (<0.70 μmol/L)      |    |       |       |    |       |
| Baseline                       | 157| 79.6 (73.3, 85.9) |     | 135| 77.4 (69.9, 84.1) |
| Final                          | 120| 39.2 (30.4, 47.9) | 106| 34.9 (25.8, 44.0) |
| Low zinc (<9.9 μmol/L)          |    |       |       |    |       |
| Baseline                       | 157| 66.2 (59.5, 72.9) |     | 135| 64.4 (56.9, 71.9) |
| Final                          | 119| 36.1 (27.1, 45.0) | 105| 42.9 (33.3, 52.4) |
| ID (PF <12 μg/L or Tfr >8.5 mg/L) |     |       |       |    |       |
| Baseline                       | 157| 32.5 (25.1, 39.8) |     | 134| 20.9 (14.0, 27.8) |
| Final                          | 119| 13.4 (7.3, 19.6) | 105| 15.2 (8.4, 22.1) |
| IDA                             |    |       |       |    |       |
| Baseline                       | 157| 21.7 (15.2, 28.1) |     | 134| 17.9 (11.4, 24.4) |
| Final                          | 119| 6.7 (2.2, 11.2) | 105| 3.8 (0.1, 7.4) | 50% REDUCTION IN PREVALENCE OF MICRONUTRIENT DEFICIENCIES OVER 6 MONTH INTERVENTION

1 Values are mean percentage (95% CI). Means in a row with superscripts without a common letter differ, \( P < 0.05 \); 2 P-value represents Pearson’s \( \chi \)-square.
WAS THERE AN EFFECT OF FORTIFIED COMPLEMENTARY FOODS ON STUNTING PREVALENCE?
EFFECT OF FORTIFIED COMPLEMENTARY FOODS HAZ GROWTH FALTERING STOPPED WITH LASTING EFFECTS 18 MONTHS LATER


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NO EFFECT OF FORTIFIED COMPLEMENTARY FOODS WHZ


NO EFFECT ??
NO EFFECT OF FORTIFIED COMPLEMENTARY FOODS WHZ

LONG – TERM EFFECTS?:

MICRONUTRIENTS WITH 5% MILK

NO EFFECT ??

ONLY MICRONUTRIENTS

**EFFECTS DUE TO REDUCED MORBIDITY?**

**TABLE 3** Incidence of morbidity in Vietnamese infants over the 6-mo intervention period including a FF or a FC or following traditional feeding practices (C)\(^1\)

<table>
<thead>
<tr>
<th></th>
<th>FF</th>
<th>FC</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>(n)</td>
<td>157</td>
<td>135</td>
<td>134</td>
</tr>
<tr>
<td>Diarrhea</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total episodes, (n)</td>
<td>62</td>
<td>12</td>
<td>156</td>
</tr>
<tr>
<td>Total days, (n)</td>
<td>110</td>
<td>21</td>
<td>581</td>
</tr>
<tr>
<td>Days/infant, (n)</td>
<td>0.7 ± 1.7(^a)</td>
<td>0.2 ± 0.6(^a)</td>
<td>4.3 ± 7.2(^b)</td>
</tr>
<tr>
<td>Fever</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total episodes, (n)</td>
<td>733</td>
<td>611</td>
<td>859</td>
</tr>
<tr>
<td>Total days, (n)</td>
<td>1911</td>
<td>1779</td>
<td>2999</td>
</tr>
<tr>
<td>Days/infant, (n)</td>
<td>12.2 ± 9.2(^a)</td>
<td>13.2 ± 0.6(^a)</td>
<td>22.4 ± 15.3(^b)</td>
</tr>
<tr>
<td>ARI</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total episodes, (n)</td>
<td>733</td>
<td>626</td>
<td>763</td>
</tr>
<tr>
<td>Total days, (n)</td>
<td>2398</td>
<td>2254</td>
<td>3036</td>
</tr>
<tr>
<td>Days/infant, (n)</td>
<td>15.3 ± 13.4(^a)</td>
<td>16.7 ± 11.8(^a)</td>
<td>22.7 ± 17.4(^b)</td>
</tr>
</tbody>
</table>

\(^1\) Values are \(n\) or means ± SD. Means in a row without a common letter differ, \(P < 0.05\).

\(^2\) \(P\)-value for the overall difference among groups, controlling for sex, village, and baseline value.

*FT Wieringa*  
*ILSI Food Fortification Bangkok 10 Oct 2013*
## Table 9
Comparison of daily intakes of total energy and macronutrients from all complementary foods as a function of the type of gruel.

<table>
<thead>
<tr>
<th></th>
<th>Favina group (n = 48)</th>
<th>Favilase group (n = 48)</th>
<th>Control group (n = 48)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Energy intake</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(kcal/day)$^1$</td>
<td>276 (253)$^a$</td>
<td>293 (203)$^a$</td>
<td>175 (151)$^b$</td>
</tr>
<tr>
<td>(kcal/kg BW/day)$^2$</td>
<td>43.1 ± 20.4$^a$</td>
<td>44.3 ± 28.2$^a$</td>
<td>28.1 ± 16.3$^b$</td>
</tr>
<tr>
<td><strong>Protein intake</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(g/day)$^4$</td>
<td>11.5 ± 5.7$^a$</td>
<td>13.7 ± 8.4$^a$</td>
<td>8.5 ± 7.1$^b$</td>
</tr>
<tr>
<td>(g/kg BW/day)$^4$</td>
<td>1.53 ± 0.73$^a$</td>
<td>1.78 ± 0.98$^a$</td>
<td>1.15 ± 0.95$^b$</td>
</tr>
<tr>
<td><strong>Lipid intake</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(g/day)$^3$</td>
<td>6.5 ± 3.1$^a$</td>
<td>6.1 ± 4.0$^a$</td>
<td>4.2 ± 2.9$^b$</td>
</tr>
<tr>
<td>(g/kg BW/day)$^4$</td>
<td>0.88 ± 0.39$^a$</td>
<td>0.79 ± 0.43$^a$</td>
<td>0.58 ± 0.41$^b$</td>
</tr>
</tbody>
</table>

$n$: Number of infants.

BW: Body weight.

Medians (interquartile ranges). Different letters in the same row indicate significantly different medians $p < 0.0001$, Mann-Whitney’s test.

$\bar{x} \pm SD$: Different letters in the same row indicate significantly different means ($^1p < 0.001$, $^2p < 0.01$, $^3p < 0.05$, Fisher Test).
## Table 11

Comparison of total micronutrient intakes (mg/day) per day from all complementary foods as a function of the type of gruel.

<table>
<thead>
<tr>
<th></th>
<th>Favina group (n = 48)</th>
<th>Favilase group (n = 48)</th>
<th>Control group (n = 48)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium&lt;sup&gt;3&lt;/sup&gt;</td>
<td>317 (294)&lt;sup&gt;b&lt;/sup&gt;</td>
<td>437 (475)&lt;sup&gt;a&lt;/sup&gt;</td>
<td>65 (103)&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Iron&lt;sup&gt;2&lt;/sup&gt;</td>
<td>14.7 (13.2)&lt;sup&gt;b&lt;/sup&gt;</td>
<td>22.1 (21.1)&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.4 (1.9)&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Zinc&lt;sup&gt;1&lt;/sup&gt;</td>
<td>4.1 (3.8)&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.1 (4.1)&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.1 (1.2)&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

\(n\): Number of infants.

Medians (interquartile ranges). Different letters in the same row indicate significantly different medians (\(^1p < 0.0001, ^2p < 0.01, ^3p < 0.05\); Mann-Whitney's test).

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Conclusion I

• A locally produced, complementary food, based on rice, soya beans and milk powder with added micronutrients could be produced for < 0.12 US$ per meal (35 g of dry product)

→ Target price could be even less (1 US$ / kg, or 0.035 US$ / meal or 0.10 US$ / day (3 meals/day)

→ This could stop growth faltering / stunting for a large part, or even completely.....
Conclusion II

• But what about this long term effect of micronutrient powders vs ‘compleet’ CF?

• Are micronutrient powders having a different effect on body composition than a compleet CF, causing long-term differences??

• What is the effect of CFs on body composition??
WINFOOD project ......

Effect of different types of complementary foods on micronutrient status and growth
Effect of animal-source foods and micronutrient-fortification complementary foods on body composition, linear growth and iron status – The WinFood project in Cambodia

Jutta Skau, MSc Public Health, PhD-Fellow
Department of Nutrition, Exercise and Sports
University of Copenhagen
The intervention products

= WF

Local milled rice + Esomus Longimanus + Paralaubuca typus + Edible spider = WF

Local milled rice + Mixed small fish + MN-premix = CSB+/++
Results – flow chart

514 children invited for screening

419 randomised

- WF 106
  - 21 left study area
    - 85 completed
    - 70 missed maximum 1 food distribution

- WF-L 104
  - 10 left study area 1 died in accident
    - 93 completed
    - 77 missed maximum 1 food distribution

- CSB++ 103
  - 14 left study area 1 died in accident
    - 88 completed
    - 71 missed maximum 1 food distribution

- CSB+ 106
  - 14 left study area
    - 92 completed
    - 70 missed maximum 1 food distribution

74 never got assessed
21 excluded: 3 severe anemic
4 WLZ<-3
4 twins
10 with chronic diseases

*Main reason of immigration was flooding
Systematic review of the efficacy and effectiveness of complementary feeding interventions in developing countries

Kathryn G. Dewey and Seth Adu-Afarwuah
Program in International and Community Nutrition, University of California, Davis,

Key messages:

1) Educational interventions that include a strong emphasis on feeding nutrient-rich animal source foods may be more likely to show an effect on child growth than interventions with more general messages about complementary feeding.
2) In areas with a high prevalence of food insecurity, complementary feeding interventions that include provision of additional food, not just education, may be more effective.
3) Interventions in which micronutrient fortification is the sole component can be effective at improving iron and vitamin A status, but they generally have little impact on growth.
4) Appropriately designed complementary feeding interventions can reduce morbidity, but caution is needed to avoid excessive displacement of breast milk and to include counseling on responsive feeding, hygienic practices and continued breastfeeding.
5) Recent studies of complementary feeding interventions have suggested a positive impact on behavioral development, which may be a more sensitive indicator of improvements in child nutrition than other outcomes.