New formulations of ready-to-use foods

Speakers: Peter Akomo and Filippo Dibari
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**Method**: How to develop novel formulations?

**Results**: How did the novel RUF perform?

What were the **conclusions** and the **recommendations**?
why novel formulations?

BACKGROUND
Background: why novel formulations?

• Not always available where needed: e.g. India  
  (Beesabathuni 2010; Gupta 2009)

• Current formulations are based on results from:  
  o limited number of studies  
  o few settings

• Low acceptability in some group of beneficiaries (e.g. adults (Dibari 2012); south-east Asia)

• Replacement of costly ingredients (e.g. milk powder)

• Integration of treatment ⇔ prevention + incorporating locally grown ingredients + avoiding reliance on imported commodities
How to develop novel formulations?

METHOD
Diet Planning in the Third World by Linear and Goal Programming

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The use of linear programming to select diets to meet specific nutritional requirements frequently results in an over-supply of certain nutrients. Nutritional balance is difficult to achieve in diets selected by linear programming owing to the complex inter-relationships of the constraints. Goal programming is presented as a method of achieving nutritional balance in selected diets. An example demonstrating the goal programming approach is followed by a report of an application of the technique to the selection from 150 food raw materials to satisfy the daily nutritional requirements of Thais. The nutritional balance of the raw materials selected by goal programming showed a marked improvement over that selected by linear programming.
Design method for novel formulations

SELECT Nutrient recommendations

APPLY Linear programming

TEST acceptability & safety

TRIAL clinical effectiveness

SELECT Food price and composition data

Improved/cheaper Ready-to-Use Food

Source: Dibari et al. (2012)
Low-Cost, Ready-to-Use Therapeutic Foods Can Be Designed Using Locally Available Commodities with the Aid of Linear Programming$^{1,2}$

Filippo Dibari,$^{3,4}$ El Hadji I. Diop,$^3$ Steven Collins,$^3$ and Andrew Seal$^4$

$^3$Valid Nutrition, Cuibin Farm, Derry Duff, Bantry, Co. Cork, Ireland; and $^4$UCL Centre for International Health and Development, Institute of Child Health, London, UK

Abstract

According to the United Nations (UN), 25 million children $<5$ y of age are currently affected by severe acute malnutrition and need to be treated using special nutritional products such as ready-to-use therapeutic foods (RUTF). Improved formulations are in demand, but a standardized approach for RUTF design has not yet been described. A method relying on linear programming (LP) analysis was developed and piloted in the design of a RUTF prototype for the treatment of wasting in East African children and adults. The LP objective function and decision variables consisted of the lowest formulation price and the weights of the chosen commodities (soy, sorghum, maize, oil, and sugar), respectively. The LP constraints were based on current UN recommendations for the macronutrient content of therapeutic food and included palatability, texture, and maximum food ingredient weight criteria. Nonlinear constraints for nutrient ratios were converted to linear equations to allow their use in LP. The formulation was considered accurate if laboratory results confirmed an energy density difference $<10\%$ and a protein or lipid difference $<5\ g\cdot100\ g^{-1}$ compared to the LP formulation estimates. With this test prototype, the differences were 7\%, and 2.3 and $-1.0\ g\cdot100\ g^{-1}$, respectively, and the formulation accuracy was considered good. LP can contribute to the design of ready-to-use foods (therapeutic, supplementary, or complementary), targeting different forms of malnutrition, while using commodities that are cheaper, regionally available, and meet local cultural preferences. However, as with all prototype feeding products for medical use, composition analysis, safety, acceptability, and clinical effectiveness trials must be conducted to validate the formulation. J. Nutr. 142: 955–961, 2012.
**Nutrients constraints**

<table>
<thead>
<tr>
<th>Constraints</th>
<th>Initial target requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>OF, cost minimization, $</strong></td>
<td>NA¹</td>
</tr>
<tr>
<td><strong>Energy and nutrients</strong></td>
<td></td>
</tr>
<tr>
<td>Energy, kJ/100 g</td>
<td>2174.0–2289.0³</td>
</tr>
<tr>
<td>Protein energy/total energy⁴, %</td>
<td>10.0–12.0</td>
</tr>
<tr>
<td>Fat energy/total energy⁴, %</td>
<td>45.0–60.0</td>
</tr>
<tr>
<td>(n-3) Fatty acid energy/total energy⁴, %</td>
<td>0.3–2.5</td>
</tr>
<tr>
<td>(n-6) Fatty acid energy/total energy⁴, %</td>
<td>3.0–10.0</td>
</tr>
<tr>
<td><strong>Palatability</strong></td>
<td></td>
</tr>
<tr>
<td>Sugar (sweetness), g/100 g</td>
<td>15.0–18.0⁵</td>
</tr>
<tr>
<td>Sorghum (taste improvement), g/100 g</td>
<td>7.0–10.0</td>
</tr>
<tr>
<td><strong>Texture-related</strong></td>
<td></td>
</tr>
<tr>
<td>Fat content (moisture), %</td>
<td>28.0–36.0</td>
</tr>
<tr>
<td>Maximum final ingredient weight</td>
<td></td>
</tr>
<tr>
<td>Final total weight, g</td>
<td>97.0</td>
</tr>
<tr>
<td><strong>Monitored variables (not included as constraints)</strong></td>
<td></td>
</tr>
<tr>
<td>Quality of protein expressed as PDCAAS, %</td>
<td>75.0–89.0⁷</td>
</tr>
<tr>
<td>TFD, %</td>
<td>NA</td>
</tr>
<tr>
<td>Limiting amino acid</td>
<td>NA</td>
</tr>
</tbody>
</table>

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**Cheapest formulation!**

- Energy and nutrients
- Palatability
- Texture-related
- Maximum food weight
- Protein quality and digestibility
Design method for novel formulations

**SELECT Nutrient recommendations**

**SELECT Food price and composition data**

**Chosen by Kenyan manufacturers among:**
- Pulses
- Cereals
- Oils
- Sugars

- Cheap but...
- ...nutritious
- Available on local market
- Culturally acceptable

**SMS - RUTF**
Design method for novel formulations

- Initial target requirements
- Optimal solution

<table>
<thead>
<tr>
<th>OF, cost minimization, $</th>
<th>NA$</th>
<th>0.07</th>
</tr>
</thead>
<tbody>
<tr>
<td>DV: weights of the selected foods$^2$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soybeans, g</td>
<td>NA</td>
<td>31.9</td>
</tr>
<tr>
<td>Maize, g</td>
<td>NA</td>
<td>15.3</td>
</tr>
<tr>
<td>Sorghum, g</td>
<td>NA</td>
<td>7.0</td>
</tr>
<tr>
<td>Oil, g</td>
<td>NA</td>
<td>27.3</td>
</tr>
<tr>
<td>Sugar, g</td>
<td>NA</td>
<td>15.5</td>
</tr>
</tbody>
</table>

Constraints

- Energy and nutrients
  - Energy, kJ/100 g
  - Protein energy/total energy$^4$, %
  - Fat energy/total energy$^4$, %
  - (n-3) Fatty acid energy/total energy$^4$, %
  - (n-6) Fatty acid energy/total energy$^4$, %
- Palatability
  - Sugar (sweetness), g/100 g
  - Sorghum (taste improvement), g/100 g
- Texture-related
  - Fat content, g/100 g
- Maximum food ingredient weight
- Final total weight, g

- Monitored variables (not included as constraints)
  - Quality of protein expressed as PDCAAS,$^6$ %
  - TFD,$^6$ %
  - Limiting amino acid

Modelled Constraints

Monitored Constraints
Design method for novel formulations

APPLY

Linear programming

Modelled Constraints

Monitored Constraints

<p>|</p>
<table>
<thead>
<tr>
<th>Calculated nutrient densities¹</th>
<th>Laboratory results²</th>
<th>Absolute difference</th>
<th>Relative difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy kJ/100 g</td>
<td>A</td>
<td>B</td>
<td>B - A = C</td>
</tr>
<tr>
<td></td>
<td>2169.0</td>
<td>2235.0</td>
<td>66.0</td>
</tr>
<tr>
<td>Protein g/100 g</td>
<td>13.0</td>
<td>15.3</td>
<td>2.3</td>
</tr>
<tr>
<td>Protein energy/total energy</td>
<td>0.10</td>
<td>0.11</td>
<td>0.01</td>
</tr>
<tr>
<td>Lipid g/100 g</td>
<td>34.6</td>
<td>33.6</td>
<td>-1.0</td>
</tr>
<tr>
<td>Fat energy/total energy</td>
<td>0.60</td>
<td>0.56</td>
<td>-0.04</td>
</tr>
</tbody>
</table>

DV: weights of the selected foods³

| Soybeans, g                   | NA                  | 31.9                |
| Maize, g                      | NA                  | 15.3                |
| Sorghum, g                    | NA                  | 7.0                 |
| Oil, g                        | NA                  | 27.3                |
| Sugar, g                      | NA                  | 15.5                |

Energy and nutrients

| Energy, kJ/100 g               | 2174.0–2299.0³      | 2169.0              |
| Protein energy/total energy²  | 10.0–12.0           | 10.0                |
| Fat energy/total energy²      | 45.0–60.0           | 60.0                |
| (n-3) Fatty acid energy/total energy³ | 0.3–2.5 | 0.9              |
| (n-6) Fatty acid energy/total energy³ | 3.0–10.0 | 10.0            |

Palatability

| Sugar (sweetness), g/100 g     | 15.0–18.0⁵          | 15.5                |
| Sorghum (taste improvement), g/100 g | 7.0–10.0     | 7.0                 |

Texture-related

| Fat content, g/100 g           | 28.0–36.0           | 34.6                |

Maximum food ingredient weight

| Final total weight, g          | 97.0                | 97.0                |

Monitored variables (not included as constraints)

| Quality of protein expressed as PDCAAS, % | 75.0–89.0⁷ | 85.7          |
| TMD, %                               | NA                  | 83.0               |
| Limiting amino acid                 | NA                  | Lysine             |
Design method for novel formulations

1. **SELECT** Nutrient recommendations
2. **APPLY** Linear programming
3. **TEST** acceptability & safety
4. **TRIAL** clinical effectiveness
5. **SELECT** Food price and composition data

Source: Dibari et al. (2012)

Improved/cheaper Ready-to-Use Food
Iron and zinc bioavailability in SMS RUF

Phytic acid / mineral molar ratios in SMS RUF

In-vitro absorption of iron and zinc in SMS RUF

**DSMP:** dry skim milk powder

**SPC:** soy protein concentrate
How did the novel RUF perform?

RESULTS
Examples: 2 formulations

- Chickpea sesame RUTF
  - Roasted chickpea and sesame

- Soybean maize sorghum RUTF
  - Extruded soybean, maize and sorghum
Chickpea sesame RUTF

- Acceptable among adults but not children
- Reversed adult HIV wasting (observational study)
- Weight gain correlated with free fat mass (BIA)
Soybean Maize Sorghum RUTF

➤ Characteristics

- Milk-free
- Peanut-free
- Well accepted among children
- Extruded soybean, maize and sorghum
Intervention: Change in haemoglobin

SMS RUTF increases haemoglobin more than standard RUTF
SMS-RUTF: Recovery rates

6-23 months (n=404)

24-59 months (n=465)

53 - 60%

INTENTION-TO-TREAT ANALYSIS
Body composition at recovery

Deuterium dilution technique

SMS-RUTF is equivalent to P-UTF in free fat mass deposition in children 6-59m
CONCLUSIONS AND RECOMMENDATIONS
Conclusions and recommendations

Conclusions

1. Possible to use Linear Programming to develop acceptable and efficacious RUF (children >2y; adults) that:
   - Are acceptable
   - Have less or no amount of milk: 3-5 times cheaper (ingredients-based calculation)
   - Use locally available ingredients: culturally acceptable
   - Are peanut-free: less risk of aflatoxin

2. Possible to integrate development and production of recipes to local agriculture

Recommendations

• To optimise for children <2y

• To further reduce antinutrients
Thank you

Contact:

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\((x \cdot n)\) Possible applications

**IDENTIFY**
Linear programming

**APPLY**
Acceptability & safety

**TEST**
Clinical effectiveness

**TRIAL**
On going (Zimbabwe): by MSF/NL & Valid

**Improved/cheaper**
Ready-to-Use Food

Source: Dibari et al. (2012)

Design, pre-testing, and trialling of lipid-based, ready-to-use foods to manage undernutrition
SMS-RUTF: Recovery rates

6-23 months (n=304)

24-59 months (n=427)

PER PROTOCOL ANALYSIS