Leveraging Native Nutrient Dense Plants in Development of Market-led Instant Fortified Grain Foods

Mario G Ferruzzi\textsuperscript{1}, Hawi Debelo\textsuperscript{2}, Cheikh Ndiaye\textsuperscript{2,3}, Hugo De Groote\textsuperscript{4}, Djibril Traore\textsuperscript{3}, John R.N. Taylor\textsuperscript{5} Betty Bugusu\textsuperscript{2} & Bruce R. Hamaker\textsuperscript{2}

\textsuperscript{1}North Carolina State University, Kannapolis, USA
\textsuperscript{2}Purdue University, West Lafayette, USA
\textsuperscript{2}Institut the Transformation Alimentaire, Dakar, Senegal
\textsuperscript{3}International Maize and Wheat Improvement Centre (CIMMYT), Nairobi, Kenya
\textsuperscript{4}University of Pretoria, Pretoria, South Africa
Who we are and where we work

Senegal
Mali
Niger
Kenya
Malawi
Prevalence of micronutrient deficiency in Sub-Saharan Africa

Vitamin A Deficiency

190 million (33.3%)
Pre-school age children

19.1 million (15.3%)
Pregnant women

Vitamin A deficiency causes 600,000 early childhood deaths and blindness in 500,000 children each year

Iron Deficiency

273,000 deaths: 45% in Southeast Asia, 31% in Africa (2004 report)

Zinc Deficiency

> 450,000 deaths annually in children <5 years of age (worldwide)

Sources:
WHO, 2009
Current Strategies to Alleviate Micronutrient Deficiencies

Supplementation

Commercial Fortification

Dietary Diversification

Biofortification

Can this translate to a presence in the market?

Our aim is to create successful models using food and nutrition-related technologies that:

- Expand millet and sorghum markets in urban/rural in Senegal, Kenya and Niger through application of food technology
- Improve nutritional quality of products
- Enabling a market-pull for fortification
- Support entrepreneurism
Opportunities with Vitamin A for developing countries

Two forms of vitamin A

- Preformed vitamin A
- Provitamin A carotenoids

Consumption patterns and losses

- Plant foods 78-88%
- 12-22%

- ~$23B of post harvest losses in Fruits and Vegetables
- ~4B in post harvest losses in cereal

(FAO/NRI 2009)
**Indigenous African proVA carotenoid-rich plants may contribute significant amounts of shortfall nutrients**

<table>
<thead>
<tr>
<th>Leafy Vegetables</th>
<th>Vitamin A (ug RE)</th>
<th>Zn (mg/g)</th>
<th>Fe (mg/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amaranthus sp.</td>
<td>327</td>
<td>0.02-8.4</td>
<td>0.3-3.8</td>
</tr>
<tr>
<td>Arachis hypogea</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Bidens pilosa</td>
<td>301-985</td>
<td>0.9-2.6</td>
<td>162-340</td>
</tr>
<tr>
<td>Brassica sp</td>
<td>0.9-1.3</td>
<td></td>
<td>27-31</td>
</tr>
<tr>
<td>Mangifera indica</td>
<td>1090.8</td>
<td></td>
<td>0.5</td>
</tr>
<tr>
<td>Chenopodium album</td>
<td></td>
<td>1.4-18.5</td>
<td>2.2-6.1</td>
</tr>
<tr>
<td>Cleome sp.</td>
<td>1200</td>
<td>0.6-0.8</td>
<td>2.6-2.9</td>
</tr>
<tr>
<td>Cucurbita pepo</td>
<td>194</td>
<td></td>
<td>1.5</td>
</tr>
<tr>
<td>Carica papaya</td>
<td>447.6</td>
<td></td>
<td>0.4</td>
</tr>
<tr>
<td>Galinsoga parviflora</td>
<td></td>
<td>1.5</td>
<td>3</td>
</tr>
<tr>
<td>Ipomeoa batatas</td>
<td>103-980</td>
<td>0.03-3.1</td>
<td>0.6-1</td>
</tr>
<tr>
<td>Manihot esculenta</td>
<td>1970</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Daucus carota</td>
<td>3057.3</td>
<td>2.1</td>
<td>2.5</td>
</tr>
<tr>
<td>Senna occidentalis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solanum sp</td>
<td>1070</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sonchus oleracea</td>
<td>985</td>
<td>0.5</td>
<td>2.7</td>
</tr>
<tr>
<td>Vernonia sp.</td>
<td></td>
<td>0.08</td>
<td>0.8-3.2</td>
</tr>
<tr>
<td>Vigna unguiculata</td>
<td>99</td>
<td>0.23</td>
<td>0.3-3</td>
</tr>
</tbody>
</table>

Food Processing can help to reach “target” consumers and create a “value chain” (Farmer-Processor-Consumer Chains)

Courtesy of H. de Groote (2016)
Low cost extrusion processing to generate quality products

Unit Operations
Conveying  
Mixing  
Shearing  
Cooking  
Forming  
Drying and Cooling

Process flow

Whole Grain
↓
Mill to grits/meal
↓
Moisture addition and equilibration
↓
Extrusion: Temperature > 115°C
↓
Drying and milling extrudate
↓
Pre-cooked flour (3-8% M.C.)
↓
Extrudate (18% M.C.)
↓
Variety of products
Role of Technology Incubation Centers and Local Processors

NIGER
- Initiated “Incubation Center”
- Fully functional processors
- 2 Equipment fabricators
- Job opportunities

Kenya
- Initiated “Incubation Center”
- Partnership with Univ of Eldoret
- Training complete on extruder

SENEGAL
- Long and successful history of working with entrepreneurs
- New and improved products
- Training processors in Dakar
- Equipment fabrication hub
Hands on training on the extrusion: (Niamey Niger)
Evaluation of Solar Drying and Co-Extrusion of cereals and provitamin A rich plants to develop naturally fortified instant porridges

Evaluation of inexpensive solar drier for generation of vitamin A rich powders

Co-Extrusion of vitamin A fruits/vegetables with Millet

Mango

Carrot

42 °C
55 °C
65 °C

72-74% pVA recovery after drying

µg PVA carotenoids per g

0 200 400 600 800 1000 1200 1400

Raw Solar Thin Layer Deyhydrate

µg/g of sample

0 10 20 30 40 50 60 70

Control (extruded DS*) Co-extruded DS-carrot Dry blend DS-carrot

a b
Fortified instant cereal porridges with micronutrient rich African plant ingredients

Formulation (Sorguhm, Millet)
40-65%

Formulation (Mango:Carrot)
Target 25% DV for Vitamin A
30%

Cereal Blend
Sorghum Millet

ProVA Carotenoid Source
Carrot Mango

Mineral Rich Plant Materials

Pilot Formulation
Target 25% DV for Fe and Zn
5-25%

Ingredients in Dry Mix (%)

<table>
<thead>
<tr>
<th>Millet/Sorghum</th>
<th>ProVA source</th>
<th>Mineral source</th>
</tr>
</thead>
<tbody>
<tr>
<td>60</td>
<td>30</td>
<td>5</td>
</tr>
<tr>
<td>55</td>
<td>30</td>
<td>15</td>
</tr>
<tr>
<td>45</td>
<td>30</td>
<td>25</td>
</tr>
</tbody>
</table>

Product Quality
Nutrient Delivery (Bioaccessibility)
Consumer Acceptability
Interactions between plant materials may impact nutrient delivery

- Leverage established synergies:
  - Vit C in baobab and hibiscus to enhance bioavailability of cereal iron
- Potential for new synergies can be explored

<table>
<thead>
<tr>
<th>Sample</th>
<th>µg RAE</th>
<th>% RDA (1–3 y) 100g</th>
<th>% RDA (14–18 y) 100g</th>
<th>% RDA (1–3 y) 200g</th>
<th>% RDA (14–18 y) 200g</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>10.88</td>
<td>3.63</td>
<td>1.55</td>
<td>7.25</td>
<td>3.11</td>
</tr>
<tr>
<td>Baobab (5%)</td>
<td>20.38</td>
<td>6.79</td>
<td>2.91</td>
<td>13.58</td>
<td>5.82</td>
</tr>
<tr>
<td>Baobab (15%)</td>
<td>30.50</td>
<td>10.17</td>
<td>4.36</td>
<td>20.33</td>
<td>8.71</td>
</tr>
<tr>
<td>Baobab (25%)</td>
<td>45.93</td>
<td>15.31</td>
<td>6.56</td>
<td>30.62</td>
<td>13.12</td>
</tr>
</tbody>
</table>
Working with local entrepreneurs is key to communication and ultimate success
In “auction” testing (200 mid-low income participants)
- No difference in preference between thick porridges
- Little difference in WTP without description
- After information is provided, consumers are willing to pay:
  - modest premium for instant flour
  - premium for added mango and carrot and micronutrients
  - Income increases overall WTP
  - Education increases WTP for instant flour

Products:
- A) traditional decorticated
- B) instant decort
- C) instant decort. flavored
- D) instant decort. fl. fortified w/ premix
- E) instant decort. fl. naturally fortified
Potential to leverage biofortified grains and tubers for such products

<table>
<thead>
<tr>
<th>Pearl millet variety</th>
<th>Iron content mg/100 flour</th>
<th>Contribution of one portion of porridge (125 g) to iron RDA of 4-5 year old consuming a vegetarian diet</th>
<th>Zinc content mg/100 flour</th>
<th>Contribution of one portion of porridge (125 g) to zinc RDA of 4-5 year old consuming a vegetarian diet</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>% of RDA</td>
<td>% of RDA</td>
<td></td>
</tr>
<tr>
<td>ICMB 92111 – Normal variety (ex. ISRA, Senegal)</td>
<td>4.79</td>
<td>1.5</td>
<td>7.5</td>
<td>3.40</td>
</tr>
<tr>
<td>Dhanashakti – Biofortified iron and zinc variety (ex. ICRISAT, India)</td>
<td>9.12</td>
<td>2.85</td>
<td>14.3</td>
<td>4.43</td>
</tr>
</tbody>
</table>

Data Courtesy of J. Kruger & J. Taylor (Univ. Pretoria)

http://www.icrisat.org/
Next steps and take away messages

• Embrace science and technology and local knowledge
• Understand the “consumer” and meet them where they are
• Look for opportunities for changes in products to meet nutrient needs in unique ways
• Foster partnerships with key entrepreneurs
• Push and pull for biofortified crops in real consumer products