Moringa and other highly nutritious plant resources: Strategies, standards and markets for a better impact on nutrition in Africa. Accra, Ghana, November 16-18, 2006

International Workshop on Moringa and Nutrition

Accra, Ghana
November 16-18, 2006

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Nutritional Benefits, Toxicology, and Health Effects of Moringa Leaf Powder vis-à-vis Treatment of Malnutrition

+ Cultivar Effect on *Moringa oleifera* Glucosinolate Content, Taste, and Performance Characteristics: A Pilot Study

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General Moringa Reviews, by:

Julia Morton

Lowell Fuglie

Manuel Palada

Martin Price

Trees for Life

National Academy of Sciences U.S.A. (just published)
Introduction ..................................................................................................................1
Summaries of Individual Species ...............................................................................6
Table 1: Potential Roles for Selected African Vegetables ........................................12
Overcoming Malnutrition .........................................................................................13
Boosting Food Security .............................................................................................19
Fostering Rural Development ..................................................................................23
Sustainable Landcare .................................................................................................28
Descriptions and Assessments of Individual Species
1 Amaranth (Amaranthus species) ..............................................................................35
2 Bambara Bean (Vigna subterranea) .......................................................................53
3 Baobab (Adansonia digitata) and related species ..................................................75
4 Celosia (Celosia argentea) .....................................................................................93
5 Cowpea (Vigna unguiculata) ................................................................................105
6 Dika (Irvingia species) .........................................................................................119
7 Eggplant (Garden Egg) (Solanum aethiopicum) ....................................................137
8 Egusi (Citrullus lanatus) and kindred plants ........................................................155
9 Enset (Ensete ventricosum) ..................................................................................173
10 Lablab (Lablab purpureus) ..................................................................................191
11 Locust Bean (Parkia biglobosa) ............................................................................207
12 Long Bean (Vigna unguiculata) ...........................................................................223
13 Marama (Tyloosema esculentum) .......................................................................235
14 Moringa (Moringa oleifera) and related species ...................................................247
15 Native Potatoes (Solenostemon rotundifolius and Plectranthus esculentus) ......269
16 Okra (Abelmoschus esculentus) ..........................................................................287
17 Shea (Vitellaria paradoxa) ....................................................................................303
18 Yambean (Sphenostylis stenocarpa) .................................................................323
Biographical Sketches of Panel Members .................................................................345
Credits .........................................................................................................................351
Overview

Nutritional Benefits, Toxicology, and Health Effects of Moringa Leaf Powder vis-à-vis Treatment of Malnutrition

1. Some risks?
   - In mice
   - In tilapia (a widely aquacultured species of fish)
   - In human beings

2. Some benefits?
   - Cancer protection
   - Combating *Helicobacter pylori* infection

Cultivar Effect on *Moringa oleifera* Glucosinolate Content, Taste, and Performance Characteristics: A Pilot Study

3. Variability
   - Taste
   - Phytochemical (glucosinolate) content
Framing the discussion:

GHANA: Children < 5 years old*

mortality rate = 111 for every 1,000 live births (11.1%)*

30% stunted (11% severe stunting)**

7% wasted (1% severe wasting)**

22% underweight (5% severe underweight)**

*Ghana Accelerated Child Survival and Development approach (ACSD); www.unicef.org

**Ghana Demographic Health Survey (2003)
Framing the discussion:

Primary Food Source vs. Nutritional Supplementation

While not mutually exclusive, these 2 strategies for using Moringa leaves address very different usage patterns and sets of needs.

They both require additional, rigorous, scientific research.
Moringa Leaf Powder vs. Malnutrition

• As A Primary Food Source
  – Dietary *replacement*
    • (substituting Moringa for something else)
    • high rate substitution (>10% of diet)
  – Famine food
    • when nothing else is available

• Treating Acute Malnutrition (Nutritional Supplementation)
  – Relief of vitamin, mineral deficiencies
  – Treating Protein-Energy Malnutrition
  – Combating stunting, wasting and failure-to-thrive in infants & children
  – Combating chronic infectious diseases
Out research interest in high rate supplementation grew out of cancer prevention experiments in which we had to administer very high rates of leaf powder to animals, to get the desired glucosinolate levels.
Effect of 40% *Moringa oleifera* leaf powder amended diet on weight gain in female ICR mice

Mice were 5-6 weeks old at initiation.

---

**Control Diet (AIN76)**

- **40% Moringa Diet**

*n=5 per diet*
Effect of high rate *Moringa* leaf powder supplementation for 38 days, on female ICR mouse organ development

<table>
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<th>40% Moringa</th>
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<tr>
<td></td>
<td>Mean</td>
<td>S.E.M.</td>
<td>Mean</td>
</tr>
<tr>
<td>Liver Ratio (g liver/g BW)</td>
<td>0.058</td>
<td>0.004</td>
<td>0.059</td>
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<tr>
<td>Colon (cm)</td>
<td>8.6</td>
<td>0.4</td>
<td>11</td>
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<tr>
<td>Norm. colon (cm/g)</td>
<td>0.22</td>
<td>0.01</td>
<td>0.36</td>
</tr>
<tr>
<td>Cecum (cm)</td>
<td>2.8</td>
<td>0.1</td>
<td>3.7</td>
</tr>
<tr>
<td>Cecum – Normalized (cm/g)</td>
<td>0.072</td>
<td>0.005</td>
<td>0.12</td>
</tr>
<tr>
<td>Colon:cecum ratio</td>
<td>3.1</td>
<td>0.1</td>
<td>3</td>
</tr>
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</table>
Comparative nutritional evaluation of raw, methanol extracted residues and methanol extracts of moringa (Moringa oleifera Lam.) leaves on growth performance and feed utilization in Nile tilapia (Oreochromis niloticus L.)

W Afuang, P Siddhuraju & K Becker
Department of Aquaculture Systems and Animal Nutrition, Institute for Animal Production in the Tropics and Subtropics, University of Hohenheim, Stuttgart, Germany
Growth performance and nutrient utilization of tilapia fed 40% dry moringa leaf powder enriched diet vs control diet.

<table>
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<tr>
<th></th>
<th>Control</th>
<th>Moringa (40%)</th>
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<tbody>
<tr>
<td>initial body weight (g)</td>
<td>16.9 ± 4.5</td>
<td>16.3 ± 4.5</td>
</tr>
<tr>
<td>body weight gain (g)</td>
<td>38.1 ± 4.5</td>
<td>14.5 ± 4.5</td>
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### Proximate composition

<table>
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<tr>
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<th>Control 1</th>
<th>Control 4</th>
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<tbody>
<tr>
<td>Dry matter</td>
<td>93.4</td>
<td>93.0</td>
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<tr>
<td>Crude protein</td>
<td>36.2</td>
<td>35.0</td>
</tr>
<tr>
<td>Crude lipid</td>
<td>8.9</td>
<td>9.9</td>
</tr>
<tr>
<td>Ash</td>
<td>10.6</td>
<td>12.1</td>
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<tr>
<td>Crude fibre</td>
<td>1.5</td>
<td>4.0</td>
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<tr>
<td>NFE</td>
<td>42.8</td>
<td>39.0</td>
</tr>
<tr>
<td>Gross energy (MJ kg(^{-1}))</td>
<td>19.9</td>
<td>20.4</td>
</tr>
<tr>
<td>NDF</td>
<td>4.1</td>
<td>13.4</td>
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<tr>
<td>ADF</td>
<td>1.8</td>
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<tr>
<td>ADL</td>
<td>0.6</td>
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<tr>
<td>Total phenols</td>
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<td>1.7</td>
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<tr>
<td>Tannins</td>
<td></td>
<td>0.5</td>
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<tr>
<td>Phytates</td>
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<td>0.6</td>
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<tr>
<td>Saponins</td>
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</table>

• Saponins (for example)

• Broad class of phytochemicals:
  • effects on livestock production well documented
  • effects on humans complex and contradictory
  • some useful for controlling cholesterol
  • others toxic or cause urticaria (skin rash)

• Moringa saponins
  • occur at substantial levels (1-5%) in Moringa oleifera leaves.*
  • don’t appear to be toxic at levels that are being consumed by people
  • might they be toxic when consumed as a large percentage of the diet?

Mekkonen et al. demonstrated cytotoxicity at a high level of extract (500 µg/ml).

“...a highly significant ... decrease in the percentage of viable hepatocytes was found after incubating the cells with the highest concentration (500 µg/ml) of the ethanol leaf and seed extracts of *Moringa stenopetala*. . .”

Is this a problem vis-à-vis supplementary feeding of human beings?

At some level, all plant extracts will have a deleterious effect on cultured cells.

How does this cytotoxicity relate to pathology and to the human condition?
(ug extract / ml of culture medium vs. grams of intake of food or food product per day)?
Effects of plant extracts on cultured Hepa1c1c7 cells

Viability (A550 - BCA)

μg/ml

Moringa Leaf Powder
Moringa Leaves (Fresh)
Broccoli
Tomato
Carrots
Cross sectional study

Consumption of >2x/day helleko (*Moringa stenopetala*):

significantly associated goitre in Gamo-Gofa, Ethiopia (p<0.005)

4.57 times more likely to have goitre than other groups

Prevalence of goitre (597 children and their parents), 51.7%, with 21.7% visible goitre.

Highly significant familial tendency for goitre (p<0.001).

“Isothiocyanate is a known goitrogenic chemical substance”

“... The presence of a small amount of cyanogenic glucosides in *M. stenopetala* leaves may have a health risk in areas of high incidence of endemic goitre as an exacerbating factor if consumed for a long period of time.”

79–89 mg cyanogenic glucosides / 100 g

However . . .

• Indeed, progoitrin (a glucosinolate) produces goitrin (an isothiocyanate), which upon breakdown produces an oxazolidonethione, that is goitrogenic.

• Indole glucosinolates are thought to have goitrogenic potential.

• *Moringa* spp. have neither progoitrin, nor significant levels of indole glucosinolates. They do, however, have thiocyanates which should be more intensively examined for their goitrogenicity (Ref. Faizi, Sidiqui, Guevera, et al.)
Hydrolysis of β-hydroxyalkenyl glucosinolates (e.g. progoitrin & napoleiferin), gives rise to β-hydroxyalkenyl isothiocyanates.

These compounds cyclize to oxazolidine-2-thiones which may have goitrogenic effects in mammals -- first observed in rabbits and designated "cabbage" goiter by Webster and Chesney (1930).

The "antinutritional" nature of the β-hydroxyalkenyl glucosinolates is discussed in a variety of published works.

Chemoprotection Beyond Broccoli: 
*Moringa oleifera* (Horseradish tree) & *M. stenopetala* (Cabbage tree): Edible, Nutritious and Medicinal Tropical Trees
Antibacterial potency of a variety of plant-derived isothiocyanates against *Helicobacter pylori*

International Consensus Conference (Feb 05): Why an edible plant-based approach to *H. pylori* treatment?

- Inexpensive
- Underserved populations ± indigenous plants
- May be effective where synthetic antibiotics are not
- Anti-inflammatory activity of ITCs may have 2° benefit against gastritis
- Prevent or ameliorate symptoms of gastritis, peptic ulcer or stomach cancer vs. complete cure?
On the one hand, the fact that many ethnic groups have consumed Moringa leaves and leaf powder for many generations is a very positive indication . . . After all, tolerance, safety, and toxicology studies are not performed on corn, wheat, squash, and groundnuts.

On the other hand, performing a safety and tolerance study like the following (just completed with broccoli sprouts) would be a reasonable undertaking. Funding must be developed for such a trial, which would then facilitate a variety of nutritional efficacy studies that global funding agencies have seemed reluctant to back so far.
For example, one could readily substitute *Moringa* leaf powder in an experimental design like the following, which we have just published:

“Widely consumed in many parts of the world, and have not caused any concern with respect to their tolerance and safety in humans. Nevertheless, a formal Phase I study of safety, tolerance, and pharmacokinetics appeared justified.”

- **Placebo-controlled, double blind, randomized clinical study**
- **Healthy volunteers -- inpatients on our clinical research unit**
- **5-day acclimatization period on a crucifer-free diet**
- **Oral intake of standardized broccoli sprout extract**
- **8-h intervals for 7 days (21 doses)**
- **32 types of hematology or chemistry tests (before, during, and after dosing)**
- **Liver (transaminases) and thyroid (TSH, T3, and T4) function examined in detail**
- **No significant or consistent subjective or objective abnormal events or toxicities**
Moringa leaves being promoted as nutritional supplement for weaning infants and nursing mothers.

Adoption as a nutritious supplement may hinge upon taste.

Taste can vary greatly amongst cultivars, from quite mild, to exceptionally pungent, astringent, and “radishy”.

Widely assumed to be germplasm-dependent (i.e. the breeding line or cultivar dictates taste).

Prior knowledge of one of the major phytochemical components of Moringa, the glucosinolates, suggests that they might be a component of this harshness of taste.

These glucosinolates, and their breakdown products (isothiocyanates), are also implicated in many of the medicinal properties of M. oleifera.
• Regional preferences regarding taste and other organoleptic, horticultural, and agronomic characteristics vary greatly.

• The taste of fresh leaves is known to vary greatly -- some of them are quite “radishy”, hot, and pungent, while others are very mild.

• To the extent that the leaves (typically dried and powdered) are suggested for use in weaning porridges, it would seem to be important to be able to suggest or provide sources of less harsh or less radishy tasting leaves.

• Although the potential aversion of infants to a very pungent gruel has not been tested scientifically, from a commonsense standpoint it would seem logical that having taste options would be beneficial.
Since at least two breeding lines (designated PKM1 and PKM2) have now been developed, and the potential health benefits that *Moringa* offers is widely recognized, we undertook a pilot study to investigate the association between pungent taste and glucosinolate levels of the leaves of this plant.

283 trees, representing 30 accessions, were grown in a randomized field plot at a single site in central Florida, USA

Sampled three times over the course of a year.

Taste was assessed by 9 or 10 individuals in a masked protocol.

In addition:

- glucosinolate content was measured
- performance was assessed and compared:
  - number of branches
  - horizontal-to-vertical branching
  - leaf size
  - tree height
  - tree girth
  - canopy biomass
## Accession designations

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<tr>
<td>Fort Myers</td>
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<td>N. Wood, Florida</td>
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<td><strong>Central America</strong></td>
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<tr>
<td>Binga Trees, Zimbabwe</td>
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$p$ for trend by harvest date was highly significant ($p < 0.001$).
These findings suggest that deliberate selection for agronomic, taste, or quality factors can be made without jeopardizing the content of one of the more important phytochemicals in *Moringa*.

However, this field trial has not been replicated across multiple soil types, climates, or geographic environments.

If intelligent efforts are to be directed towards producing and disseminating plants with a specific taste (e.g. mild) for specific purposes (e.g. weaning food), baseline information on these qualities must first be developed.

Ultimately, it will be necessary to determine the degree to which harshness of taste is controlled by the genetics of a cultivar, variety, or accession, and by the environmental conditions in which the plants are grown (soil type, water status, amount of heat, drought, and pathogen stress, etc.).

Leaf or foliage production (e.g. biomass) must also be better characterized.

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