African Indigenous Vegetables, a Neglected Treasure, for Improved Nutrition and Income in Eastern and Southern Sub-Saharan Africa

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# Projected Population Growth (billions)

<table>
<thead>
<tr>
<th>Region</th>
<th>2011</th>
<th>2050</th>
<th>Change</th>
<th>Percent</th>
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<tbody>
<tr>
<td>World</td>
<td>6.9</td>
<td>9.5</td>
<td>+2.6</td>
<td>+ 38</td>
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<tr>
<td>High Income</td>
<td>1.2</td>
<td>1.3</td>
<td>+ 91</td>
<td>+ 7</td>
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<tr>
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<td>8.2</td>
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<td>+ 44</td>
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<td>2.2</td>
<td>2.3</td>
<td>+ 125</td>
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<td>South Central Asia</td>
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<td>2.6</td>
<td>+ .8</td>
<td>+ 43</td>
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<td>2.0</td>
<td>+1.1</td>
<td>+134</td>
</tr>
<tr>
<td>Lat. America/Carib</td>
<td>.6</td>
<td>.7</td>
<td>+ 150</td>
<td>+ 25</td>
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<tr>
<td>N. Africa &amp; W. Asia</td>
<td>.45</td>
<td>.73</td>
<td>+ .27</td>
<td>+ 61</td>
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</tbody>
</table>

State of Nutrition in Sub-Saharan Africa: Case studies from Kenya and Zambia*

- Undernutrition is decreasing in many developing regions but parts of SSA have only begun “nutrition transition”;
- Efforts to reduce undernutrition must focus on reducing undernutrition w/o promoting excess weight gain;
- Economic advances must consider integrated approaches to improved household economics w/o increasing over-nutrition;
- Advance maternal education & household wealth w/o introducing processed foods and/or foods not of traditional diets;
Why Focus on African Indigenous Vegetables (AIVs)?

- AIVs address serious undernutrition problems in sub-SSA;
- AIVs are a mainstay in traditional diets;
- Neglected crops ~ 400 species, rich history and locally adapted;
- Not normally cash crops but with growing urban markets have potential for income generation to smallholders;
- Our research can overcome periods of abundance and periods of scarcity through improved production practices and scheduling;
- Many AIVs contain high essential nutrients, proteins, vitamins, minerals and possible medicinal/health properties;
- Natural bridge linking agriculture and improved nutrition and health.
Horticulture Innovation Lab Nutrition Research Program:

- Goal of program is to improve production and increase consumption of AIVs to improve nutrition, generate income and improve health of nutritionally at risk populations in Eastern and Central Zambia and Western Kenya;

- Program builds upon a previous studies showing significant interest and acceptance of AIVs by rural farmers;

- We use the Rutgers Models of Market-First and Science Driven Development for Income Generation and Increased AIV Consumption.
Challenges

• Need greater understanding to current best intervention practices that will lead to increased consumption of fresh produce including AIVs;

• Rural communities and peri-urban households need greater access to affordable AIVs;

• AIVs often unavailable particularly during dry seasons;

• Strengthening of AIV value chains needed from access to improved varieties, fertilizer, other inputs. SWOT analyses have conducted in Kenya and Zambia (with 200 producers and >50 intermediaries in each country) to identify the gaps and from that to build interventions programs to meet those needs.
Considerations

- Project findings indicate in the targeted rural and peri-urban households in W. Kenya and E. and central Zambia AIVs are known to > 90% of the populations. AIVs in these countries are viewed as culturally acceptable, desired as preferred food options, yet rarely to periodically consumed.

- This translates to a potential untapped market demand (millions of dollars) and major economic opportunity for growers and > consumers access to nutrient rich foods of interest to them.

- Our systems approach has enhanced access and adoption (production and consumption) and leading to significant new income generation opportunities to those not previously involved in commercial horticulture production; and a greater awareness to nonproducing communities of the AIV nutritional and health value.
Horticulture Innovation Lab Nutrition Research Program Builds Upon the 4 A’s:

- Access
- Affordability
- Availability
- Adoption* (Increased Consumption, and to others increased production)


Leading to Measureable Health Indicators in targeted populations in Kenya & Zambia
Factors Impacting Nutritional Success

- Access
- Knowledge
- Resources

- Control over spending
- Livelihoods
- Seasonality

- Gender
- Access
- Control
- Resources

- Age
- Pregnancy/lactation

Technical Factors

Financial Factors

Household dynamics

Biological & Cultural factors
## Frequency of AIV Consumption

### Pilot Survey Zambia

<table>
<thead>
<tr>
<th>AIV</th>
<th>Rarely</th>
<th>Sometimes</th>
<th>Everyday</th>
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<tr>
<td>Green Maize (fresh)</td>
<td>66.7</td>
<td>29.4</td>
<td>3.9</td>
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<tr>
<td>Amaranth</td>
<td>24.1</td>
<td>69.0</td>
<td>6.9</td>
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<tr>
<td>Nightshade</td>
<td>46.2</td>
<td>53.8</td>
<td>0</td>
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<tr>
<td>Spider Plant</td>
<td>39.1</td>
<td>60.9</td>
<td>0</td>
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<tr>
<td>Cowpea</td>
<td>59.1</td>
<td>40.9</td>
<td>0</td>
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<tr>
<td>Jute Mallow</td>
<td>23.1</td>
<td>76.9</td>
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<tr>
<td>Kale</td>
<td>26.1</td>
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<td>4.3</td>
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<tr>
<td>Sweet potato leaves</td>
<td>28.6</td>
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<td>0</td>
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<tr>
<td>Orange sweet potato</td>
<td>64.3</td>
<td>35.7</td>
<td>0</td>
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<tr>
<td>Okra</td>
<td>26.9</td>
<td>73.1</td>
<td>0</td>
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<tr>
<td>Ethiopian mustard</td>
<td>35.3</td>
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<td>0</td>
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<tr>
<td>African eggplant</td>
<td>41.4</td>
<td>58.6</td>
<td>0</td>
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<tr>
<td>Other AIVs</td>
<td>28.6</td>
<td>71.4</td>
<td>0</td>
</tr>
</tbody>
</table>

1=Rarely (once a month); 2=Sometimes (1-2 times a week); 3=Every day (6-7 times a week)
Obj. 1 Hypothesis: Appropriate Interventions can Increase Access to and Consumption of AIVs Among Producers & Consumers in Kenya & Zambia.

Lesson 1. Developing & identifying the most effective intervention methods toward improved access, affordability, availability, and adoption of AIVs must be based on solid survey consumer data.

Pilot survey’s conducted indicated:
1. AIVs very popular - but not consumed regularly!
2. Kenya’s and Zambians would opt to consume AIVs (at greater frequency and quantities) but don’t due to issues of access, affordability, availability, with many unaware of their nutritional benefit.
3. Preference for specific AIV and their popularity drives our R&D.

Assessing the context, determine and report the nutritional status, dietary intake and diversity, and AIV consumption for adults in Kenya and Zambia initially using published data and existing datasets.

Food and nutrient intake: Data is being analyzed to determine the following:
- Nutritional status
- Dietary diversity
- AIV consumption by gender, geographical area, season, and income.
Women’s Dietary Diversity
Lessons Learned from Pilot Study in Kenya and Zambia

- Collected data on household consumption and dietary diversity
- Data used to inform subsequent baseline data collection in 2016
  Average WDD score was below 5, indicating low dietary diversity
  WDD is a robust outcome that will allow for differentiation between groups studied in 2017 and 2018
500 households with at least one woman of childbearing age and at least one child were surveyed in both Kenya and Zambia in 2016 to evaluate baseline AIV production & consumption in communities prior to intervention activities.

Our Approach:
125 households are now either being provided with: (T1) Nutrition education intervention activities; (T2) Production intervention activities; (T3) Both types of intervention activities; and (T4) A Control group treatment.

Follow-up consumption surveys following intervention activities will allow a quantitative evaluation of the effect of each intervention approach.
Lesson 2: 98.8% producers want access to better management practices, technology and pest management
Action Plan - Promote AIV Cultivation, Marketing & Consumption

• AIV intervention for producers consists of a series of discrete activities to promote AIV cultivation and marketing for those providing fresh produce to informal and formal market.

• One goal of AIV intervention is to increase availability of AIVs in target communities all year long!

• Nutrition program and the nutrition interventions are different and will:
  • Evaluate if learning about the nutritional and health benefits of AIV increases consumption among non-producers as our primary dietary diversity surveys and goals are to increase consumption and adoption of AIVs when they are accessible, affordable and available. That is, our primary focus is on consumers that are not involved with actual production of AIVs within select communities of Kenya and Zambia.
Nutritional Evaluation of AIV Intervention

• Determine change in AIV consumption and dietary quality between a community that participates in the intervention and a control community.

• Assess change in AIV consumption and dietary quality following study for consumption patterns and to determine appropriate nutritional interventions.
Nutrition Education Intervention (BCC)

500 Individuals in Kenya and 500 in Zambia will be provided with on-going nutrition education trainings (BCC):

- Nutrition content of AIVs
- Recommended intake amount
- Health Applications
- Recipes and meal preparations

Lesson 4 Learned: Parents, grandparents and even school teachers far more excited about AIVs when they understand their nutritional content! Source of pride, source of tradition, easy to collect yet still perceived to be wild harvested not cultivated and “undervalued.”
Obj. 2: Hypothesis: Appropriate Promotion and Expansion of Availability of AIVs at the Local Level will Strengthen Market Access and Sales for Producers of AIVs:

In each Zambia and Kenya, 300 AIV producers and 75 intermediaries were surveyed to identify the most substantial bottlenecks in productivity to guide the focus of production interventions.

Lesson 3. Growers report AIV requires same level of management and skills as vegetables and report difficulties in:

* Access to seeds and plant materials; unaware of improved germplasm; identified problems with some current AIVs; high price of fertilizers and farm credit limiting, and insect problematic with a few AIVs. 75% of producers cant access credit (agric. inputs after medical bills identified as primary use of credit)
Obj. 2: Hypothesis: Appropriate Promotion & Expansion of Availability of AIVs at the Local Level will Strengthen Market Access and Sales for Producers of AIVs: (Production & Preferences of AIVs)

- **Org. Sweet Potato**
- **Cowpea**
- **Spider plant**
- **Nightshade**
- **Amaranth**

- Opportunity to earn extra income
- Home consumption
- Production Experience
- Good Prices

Note: Rest of the % belongs to Other AIV’s
Where do Farmer get Their African Traditional Vegetables Seeds?

- Ag. Dealers
- ASNAPP
- Farmers & Friends
- Shop & Local
- Own farm & Recycled
- Others

Amaranth
- Shop & Local
- Own farm & Recycled

Nightshade
- Ag. Dealers
-ASNAPP
- Farmers & Friends

Spider plant
- ASNAPP
- Farmers & Friends
- Others

Cowpea
- Ag. Dealers
- ASNAPP
- Farmers & Friends

Orange Sweet Potato
- Ag. Dealers
- ASNAPP
- Own farm & Recycled
AIVs Trading Partners

- Direct to consumers, 73%
- Wholesalers, 18%
- Retailers, 4%
- Roadside stands, 3%
- Supermarkets, 1%
- Brokers, 1%
- Direct to consumers, 73%
Constraints in AIV Farming

- Lack of seed or plant materials
- High price of fertilizer
- High prices of improved seed
- Pests & Diseases
- Poor vegetable leaf market prices
- Lack of credit to buy fertilizer

Plant Varieties:
- Spider plant
- Amaranth
- Night shade
Obj. 3. Determine Best Management Practices for AIV Production, Increase Capacity and Access to AIVs

Participatory research prioritized by survey results to provide accurate information and recommendations for farmers

- Cultural practices
- Management technologies
- Improved seed, collection
- Integrated pest management
- Irrigation and drought tolerance

Lesson 5: 90.9% producers want better AIV seed quality.
Lesson 6: 75% of producers want training for production during dry seasons & drought.

Solar Dryer < $100 to build
Lesson 7: Selection and breeding for micronutrients possible.


Result: A new high Fe Amaranth being developed by us with new variety release expected in 2017/2018.

Lesson 8: Many of the AIVs are nutrient rich and can be submitted to USDA for inclusion.

Result: Spiderplant flower rapidly ca. 1 month in field limiting production. We then screened populations for photoperiodicity. In 2016 we identified spiderplants that remain vegetative for >6 months, and now field testing. This could be transformative!

AMMI results

<table>
<thead>
<tr>
<th></th>
<th>Fe</th>
<th>Ca</th>
<th>Mg</th>
<th>Zn</th>
<th>Total Yield</th>
<th>Height</th>
<th>Spread</th>
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<td>&lt;.0001</td>
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<td>0.0085</td>
<td>0.0035</td>
<td>0.088</td>
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</table>

Results of additive main effects and multiplicative interaction effect (AMMI) analysis of the four accessions which were grown in common across the three environments: PI 674263, AC-NL, AH-TL, and Madiira 1.
Vegetable Amaranth Nutrition Performance

- Ca and Mg “high source” in all genotypes and environments
- Zn below “source” in all genotypes and environments
- Fe above “high source” and below “source” by genotype

Genotype | fe   | ca   | mg   | zn    |
----------|------|------|------|-------|
AM8       | 160.34 | 3.4758 | 1.9398 | 41.839 |
AM14      | 148.33 | 4.0381 | 1.7607 | 61.63  |
AM24      | 360.41 | 3.692  | 1.6943 | 55.314 |
AM27      | 254.8   | 3.7582 | 1.8788 | 52.517 |
AM31      | 199.54 | 3.5718 | 1.4389 | 51.726 |
AM32      | 210.89 | 3.8    | 1.6968 | 59.985 |
AM33      | 213.3  | 3.6055 | 1.7481 | 54.358 |
AM34      | 169.53 | 3.9695 | 2.1033 | 36.201 |
AM35      | 178.97 | 4.6012 | 2.0326 | 39.718 |
AM36      | 190.98 | 3.8607 | 2.1884 | 40.375 |
AM38      | 175.53 | 4.2259 | 1.5637 | 60.26  |
AM39      | 196.7  | 3.9946 | 1.9168 | 41.34  |
AM41      | 237.24 | 3.9771 | 2.2201 | 40.877 |
AM44      | 351.41 | 4.5105 | 1.7015 | 67.692 |
AM71      | 302.91 | 4.5803 | 1.9205 | 48.548 |
AM72      | 293.62 | 4.5546 | 1.8938 | 53.589 |
AM74      | 212.83 | 4.2476 | 1.8557 | 45.006 |
AM80      | 254.95 | 4.1516 | 1.922  | 57.43  |
AM81      | 275.11 | 4.6748 | 2.0032 | 63.54  |
AM101     | 323.79 | 3.9253 | 1.9197 | 54.955 |
AM107     | 355.43 | 3.9167 | 1.6103 | 48.888 |

Fig. Tukey’s mean separation analysis run on SAS on a single field evaluation. Genotypes are not significantly different from other genotypes with the same letter for each trait.
# Vegetable Amaranth Field Performance

<table>
<thead>
<tr>
<th>Genotype</th>
<th>Totyield</th>
<th>Totyield</th>
<th>height</th>
<th>spread</th>
<th>market yield</th>
<th>market yield</th>
<th>market prop</th>
<th>market prop</th>
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</thead>
<tbody>
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<td>bc</td>
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<td>31.6</td>
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<td>d</td>
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<td>d</td>
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</table>

Fig. Tukeys mean separation analysis run on SAS on a single field evaluation. Genotypes are not significantly different from other genotypes with the same letter for each trait.
Multi-environment Nutrition Content of Vegetable Amaranth

- Results show we can select for high source iron varieties
- Further selection for high source levels of Ca and Mg unnecessary
### Vitamin E (α-tocopherol) Content of *Amaranthus* spp. Lines (IU/100g)

<table>
<thead>
<tr>
<th>Line</th>
<th>α-Tocopherol (IU/100g)</th>
<th>α-Tocopherol (mg/100g)</th>
<th>β-Carotene (IU/100g)</th>
<th>β-Carotene (mg/100g)</th>
<th>Polyphenols (GAE/gram)</th>
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<tr>
<td>A. cruentus (AM-33)</td>
<td>&lt;0.517</td>
<td>1.00±0.45</td>
<td>&lt;0.77</td>
<td>1659.91±750.14</td>
<td>2.21±0.39</td>
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<td>A. hybridus (AM-14)</td>
<td>1.13±0.02</td>
<td>3.97±1.01</td>
<td>1.68±0.03</td>
<td>6585.15±1681.74</td>
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<tr>
<td>A. tricolor (AM-80)</td>
<td>1.03±0.12</td>
<td>4.85±0.56</td>
<td>1.54±0.17</td>
<td>8049.65±923.98</td>
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<tr>
<td>Spinach*</td>
<td>2.38</td>
<td>3</td>
<td>3.55</td>
<td>4980</td>
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*USDA online; ** Indian J. Med. Res. 71, 1980 pp
Spiderplant (Cleome spp.)

Vitamin E (α-tocopherol-blue) and β-carotene (red) content of Cleome spp. accessions (mg/100g)

<table>
<thead>
<tr>
<th>Accession</th>
<th>α-Tocopherol (mg/100g)</th>
<th>β-Carotene (mg/100g)</th>
<th>α-Tocopherol (IU/100g)</th>
<th>β-Carotene (IU/100g)</th>
<th>Polyphenols (GAE/gram)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C. gynandra (SP-16)</td>
<td>3.04±1.77</td>
<td>5.37±4.03</td>
<td>4.54±2.64</td>
<td>8924.00±6688.92</td>
<td>3.53±0.89</td>
</tr>
<tr>
<td>C. rubella (SP-11)</td>
<td>3.67±1.27</td>
<td>4.40±1.08</td>
<td>5.47±1.90</td>
<td>7313.15±1793.79</td>
<td>10.00±0.87</td>
</tr>
<tr>
<td>C. hirta (SP-9)</td>
<td>5.55±1.83</td>
<td>7.70±3.68</td>
<td>8.29±2.72</td>
<td>12790.75±6107.05</td>
<td>6.84±1.35</td>
</tr>
<tr>
<td>C. gynandra (SP-5)</td>
<td>7.32±2.21</td>
<td>17.80±4.80</td>
<td>10.92±3.30</td>
<td>29551.45±7972.55</td>
<td>6.60±0.96</td>
</tr>
<tr>
<td>Spinach*</td>
<td>2.38</td>
<td>3</td>
<td>3.55</td>
<td>4980</td>
<td></td>
</tr>
</tbody>
</table>

*USDA online; ** Indian J. Med. Res. 71, 1980 pp
**Nightshade (Solanum spp.)**

<table>
<thead>
<tr>
<th>Accession</th>
<th>mg α-tocopherol/100g</th>
<th>mg β-carotene/100g</th>
<th>IU α-tocopherol/100g</th>
<th>IU β-carotene/100g</th>
<th>Polyphenols (GAE/gram)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S. Scabrum (NS-2)</td>
<td>10.69±0.20</td>
<td>7.41±0.45</td>
<td>15.95±0.67</td>
<td>12302.07±752.98</td>
<td>3.83±0.35</td>
</tr>
<tr>
<td>S. Nigrum (NS-3)</td>
<td>11.49±0.86</td>
<td>8.51±0.37</td>
<td>17.14±0.56</td>
<td>14120.08±619.71</td>
<td>7.31±0.37</td>
</tr>
<tr>
<td>S. Nigrum (NS-4)</td>
<td>9.04±0.37</td>
<td>6.23±0.04</td>
<td>13.49±0.05</td>
<td>10343.37±58.46</td>
<td>Pending</td>
</tr>
<tr>
<td>S. Nigrum (NS-5)</td>
<td>14.13±0.19</td>
<td>9.37±0.28</td>
<td>21.10±0.41</td>
<td>15555.23±460.88</td>
<td>Pending</td>
</tr>
<tr>
<td>S. Nigrum (NS-6)</td>
<td>6.41±0.28</td>
<td>6.27±0.20</td>
<td>9.57±0.29</td>
<td>10411.42±326.37</td>
<td>Pending</td>
</tr>
<tr>
<td>S. Americanum (NS-10)</td>
<td>14.55±0.52</td>
<td>9.61±0.37</td>
<td>21.71±0.56</td>
<td>15947.41±621.35</td>
<td>Pending</td>
</tr>
<tr>
<td>S. Nigrum (NS-13)</td>
<td>22.97±1.99</td>
<td>13.88±1.09</td>
<td>34.28±1.63</td>
<td>23047.75±1810.53</td>
<td>Pending</td>
</tr>
<tr>
<td>S. villosum (NS-18)</td>
<td>11.43±0.36</td>
<td>13.54±0.36</td>
<td>17.05±0.54</td>
<td>22483.78±602.64</td>
<td>5.76±0.79</td>
</tr>
<tr>
<td>Spinach*</td>
<td>2.38</td>
<td>3</td>
<td>3.55</td>
<td>4980</td>
<td></td>
</tr>
</tbody>
</table>

*USDA online; ** Indian J. Med. Res. 71, 1980 pp 53-56
Possible Anti-Nutritive Properties - Are Alkaloids Present?

Leaf extracts of *Solanum nigrum* (USDA PI 312110) by HPLC-ESI-MS revealed a lack of alkaloids, yet are rich source of saponins, which are oxygenated analogues of nitrogenous alkaloids. These can be either good (=bioactive & improve health) or exhibit anti-nutritive properties. **BUT:** the fruit contained high levels of both alkaloids & saponins.

<table>
<thead>
<tr>
<th>No.</th>
<th>Retention time(min)</th>
<th>compounds tentative identification</th>
<th>molecular ions and fragments identification (HPLC-ESI-MS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>9.5</td>
<td>dehydrodiosgenin-G-G-R-R</td>
<td>[M+ACN]⁺ 1069.9, [M+H]⁺ 1030.0 883.8, 737.7, 575.6 413.6</td>
</tr>
<tr>
<td>2</td>
<td>10.5</td>
<td>diosgenin-G-G-R-R (isomer 1)</td>
<td>[M+ACN]⁺ 1071.9, [M+H]⁺ 1031.9 885.9, 739.8, 577.7, 415.5</td>
</tr>
<tr>
<td>3</td>
<td>12.6</td>
<td>diosgenin-G-G-R-R (isomer 2)</td>
<td>[M+H]⁺ 1031.6 885.7, 739.7, 577.6</td>
</tr>
<tr>
<td>4</td>
<td>14.3</td>
<td>diosgenin-G-G-R-R (isomer 3)</td>
<td>[M+H]⁺ 1031.6 885.5, 739.6, 577.6</td>
</tr>
<tr>
<td>5</td>
<td>21.8</td>
<td>hydroxydiosgenin-G-R-R-R</td>
<td>[M+H]⁺ 885.7, 739.7, 593.6 431.6, 413.6</td>
</tr>
<tr>
<td>6</td>
<td>25.2</td>
<td>trihydroxytigogenin-G-R</td>
<td>773.5, 627.5 465.5, 433.5</td>
</tr>
<tr>
<td>7</td>
<td>36.6</td>
<td>dehydrodiosgenin-G-R-R</td>
<td>[M+Na]⁺ 889.8, [M+H]⁺ 867.6, 721.6, 575.5 413.5</td>
</tr>
<tr>
<td>8</td>
<td>37.9</td>
<td>diosgenin-G-R-R</td>
<td>[M+Na]⁺ 891.9, [M+H]⁺ 869.7 723.6, 577.5 415.5</td>
</tr>
<tr>
<td>No.</td>
<td>retention time/min</td>
<td>Compounds tentative identification</td>
<td>molecular ions and fragment identification</td>
</tr>
<tr>
<td>-----</td>
<td>-------------------</td>
<td>----------------------------------</td>
<td>------------------------------------------</td>
</tr>
<tr>
<td>1</td>
<td>10.5</td>
<td>solasodine-G-G-R (solasonine)</td>
<td>[M+H]+ 884.8  738.6, 576.7  414.7</td>
</tr>
<tr>
<td>2</td>
<td>12.8</td>
<td>solasodine-G-R-R (solanargine)</td>
<td>[M+H]+ 868.9  722.8, 576.8  414.7</td>
</tr>
<tr>
<td>3</td>
<td>18.6</td>
<td>hydroxyldiosgenin-G-G-R-G</td>
<td>[M+ACN]+ 1103.6, [M+H]+ 1063.4  901.6, 755.6, 593.6  431.7</td>
</tr>
<tr>
<td>4</td>
<td>19.9</td>
<td>hydroxyldiosgenin-G-R-R</td>
<td>[M+ACN]+ 1087.9, [M+H]+ 1047.5  901.7, 755.7, 593.5  431.6</td>
</tr>
<tr>
<td>5</td>
<td>21.3</td>
<td>solasodine-G-R X R</td>
<td>[M+H]+ 954.9  808.8, 722.9, 576.8  414.7</td>
</tr>
<tr>
<td>6</td>
<td>22.4</td>
<td>diosgenin-G-G-R-R-G</td>
<td>[M+H]+ 1193.6  1031.6, 885.7, 739.7, 577.6  415.6</td>
</tr>
<tr>
<td>7</td>
<td>23.0</td>
<td>tigogenin-G-G-R-R-G</td>
<td>[M+H]+ 1195.6  887.7, 741.7, 579.6  417.6</td>
</tr>
<tr>
<td>8</td>
<td>24.1</td>
<td>diosgenin-G-G-R-R</td>
<td>[M+H]+ 1031.9  885.8, 739.8, 577.6  415.5</td>
</tr>
<tr>
<td>9</td>
<td>25.2</td>
<td>diosgenin-G-G X P</td>
<td>[M+ACN]+ 1071.9, [M+H]+ 1031.6, 899.7 (? 739.7, 577.6, 415.5</td>
</tr>
<tr>
<td>10</td>
<td>25.8</td>
<td>diosgenin-G-G-R-X R</td>
<td>[M+H]+ 1117.9  971.7, 885.8, 739.7, 577.6  415.6</td>
</tr>
<tr>
<td>11</td>
<td>27.7</td>
<td>diosgenin-G X (possible isomer of 10)</td>
<td>[M+H]+ 1181.8  1043.9, 751.7 (? 577.7  415.6</td>
</tr>
<tr>
<td>12</td>
<td>29.3</td>
<td>diosgenin-G-G X R</td>
<td>[M+H]+ 1129.6  983.6, 739.6, 577.6  415.6</td>
</tr>
<tr>
<td>13</td>
<td>34.5</td>
<td>dehydrodiosgenin-G-R X-R-X</td>
<td>1149. (? 953.6, 807.5 (? 721.5, 575.6  413.5</td>
</tr>
<tr>
<td>14</td>
<td>41.1</td>
<td>diosgenin-G-R-R</td>
<td>[M+H]+ 869.7  723.6, 577.5  415.5</td>
</tr>
<tr>
<td>15</td>
<td>42.3</td>
<td>tigogenin-G-R-R</td>
<td>[M+H]+ 871.5  725.7, 579.6  417.6</td>
</tr>
</tbody>
</table>

G—glucosyl, galactosyl or other hexosyl; R—Rhamnosyl; P—xylosyl, apiosyl, or other pentosyl; X—Unidentified fragment, with corresponding side piece marked by “?”. Molecular ions protonated in orange and adducted with acetonitrile in red, aglycone fragment in blue, fragment unidentified in green.
### Nutritional Benefit of Moringa: Mineral Content Comparison

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Range of Milligram Nutrient/100g sample</th>
<th>Daily Value (%)*</th>
<th>Source Threshold**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron</td>
<td>13-41</td>
<td>72-225%</td>
<td>High</td>
</tr>
<tr>
<td>Magnesium</td>
<td>260-380</td>
<td>65-95%</td>
<td>High</td>
</tr>
<tr>
<td>Calcium</td>
<td>1330-1870</td>
<td>133-187%</td>
<td>High</td>
</tr>
<tr>
<td>Zinc</td>
<td>1.6-3.2</td>
<td>11-21%</td>
<td>High</td>
</tr>
</tbody>
</table>

*Daily Value Based on FDA standards; **Threshold based on Codex Alimentarius standards

Figure: Compares the mineral composition of Moringa dried leaves grown in Zambia in this project with both the FDA and CODEX for daily values and threshold respectively. Moringa is both a high source of Iron and Zinc, making it a very important crop for cultivation in areas such as Zambia.
Sustainable production for more resilient food production systems: case study of African indigenous vegetables in eastern Africa

S.C. Weiler*t, E. Van Wyk† and J.J. Simon§

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Abstract

African indigenous vegetables are an important crop for providing nutrition, improved health and income security to African populations. Often considered as underutilized crops, these low-input and localized fruits and vegetables generally harvested from wild populations are easy to grow, often require lower inputs than the European and ‘western’ vegetables, are more adapted to local conditions and environmental stress, and could provide local opportunities for income generation and improving health and nutrition. This paper focuses on the incorporation of African indigenous vegetables as additional crop enterprises in their traditional agroecosystems to provide more resilient food production systems for smallholder farmers in sub-Saharan Africa. This work highlights only a few such indigenous vegetables including amaranth (Amaranthus spp.), African nightshade (Solanum asparagum, S. edulis) and spiderplant (Clome gynandra) while others including African kale (Brassica oleracea), pumpkins (Cucurbita spp.), cowpea (Vigna unguiculata) and African eggplant (S. aethiopicum) are common staple crops for smallholder farmers and rural populations in eastern Africa. We posit that by strengthening the African Indigenous Vegetables (AIVs) using a market-first approach to overcome constraints along the value chain leading to improved production practices, supply, postharvest handling, distribution and consumer acceptability of AIVs, opportunities for smallholder farmers to become more engaged in the supply chain will emerge. These key ingredients are needed to develop a sustainable and resilient AIV system providing opportunities to smallholders. We suggest that focus is needed first on improving AIV genetic materials, then ensuring systems are put in place for growers to access such materials, coupled with the development of sustainable production and postharvest systems that allow for year-round production as well as seed production/saving techniques. By doing this in parallel and in partnership with industry and the private sector, greater gains can be made in improved market access and building capacity of stakeholders through outreach programs across the AIV value chain while creating awareness of health and nutritional benefits of AIVs which further serve to drive market demand.

Keywords: African indigenous vegetables, traditional vegetables, amaranth, moringa, mung beans, pumpkins, African nightshade, Solanum asparagum, S. edulis, S. aethiopicum, diversity, health and nutrition, income generation, market-first, science-driven.

Introduction

Sub-Saharan Africa (SSA) is the only major region in the world where poverty is increasing rather than decreasing. Where human development indicators are worsening. An estimated 925 million of the world’s population are undernourished. Of these, 239 million (representing 26%) are inhabitants of sub-Saharan Africa (FAO, 2018) and
Increasing Access: Peri-Urban; Urban, Schools

Evaluating Sack-Gardens: Tumaini Center for Street Boys, Kenya

Our Project is:
Providing Training in AIV production, research methods and marketing to the boys and assisting in farm productivity

Lesson 9: Linking to Youth within our project provides new avenue to reach ‘new generation of farmers’, urban gardening/farming and families to improve health and generate income
Challenges

• Need greater understanding as to current best intervention practices that will lead to increased consumption of fresh produce including AIVs.

• Rural communities and peri-urban households need greater access to affordable AIVs.

• AIVs often unavailable particularly during dry seasons.

• Strengthening of AIV value chains needed from access to improved varieties, fertilizer and more. SWOT analyses have been conducted in both Kenya and Zambia (with 200 producers and >50 intermediaries in each country) to identify the gaps; dietary diversity studies now ongoing in Kenya and Zambia.
Considerations

• Project findings indicate that in the targeted rural and peri-urban households in western Kenya and Eastern and central Zambia AIVs are known to over 90% of the populations and viewed as culturally acceptable, desired as preferred food options but they are still rarely to periodically only consumed. This translates to a potential untapped market demand of millions.

• A systems approach to enhance access, and adoption (production and consumption) has been leading to significant new income generation opportunities to those that were not previously involved in commercial horticulture production and a greater awareness to communities of their nutritional and health value.
Lessons Learned

- Small-holder farmer yields of AIVs limited due to poor soils, low fertility, low inputs, lack of knowledge, and not considered ‘commercial crops’.
- Improved varieties recognized by growers are needed.
- Improved water management needed
- Pest management important and > knowledge needed
- Improved postharvest handling from farm-storage-cleaning/grading & transportation
- Need collection centers/aggregation points for bulking
- Educational and outreach programs are effective to increase interest and awareness of the benefits of AIVs.
- New introduced AIV lines (mostly originating from collaboration with WVC) are being well accepted by growers. 2 of these cvs of Amaranth & NS approved in Kenya for sale
Key Takeaways To Date:

- Households and communities in rural areas are far more interested in AIVs (and all horticultural crops) when growing them can generate yearly income streams and when there is greater access to use AIVs in their own household preparations.
- Using a market-first approach, including surveys and focus groups concerning what they now consume vs. what they would consume is effective in planning interventions and to create build-in sustainability strategies.
- Effective BCC venues can be identified by community members.
- The AIVs targeted in these studies are among those selected by those surveyed and which can be scientifically shown to be nutrient rich.
- Nutritional benefits can be a key driver in the increased consumption & trade in indigenous plants such as AIVs.
Key Takeaways To Date, con’t:

- Our key goal is to link and bridge horticultural production by producers to increased consumption by consumers using the four ‘A’s: Access, Availability, Affordability, and Adoption.

- For growers: Adoption = producing the AIVs and possibly consuming them.

- For others, Adoption means purchasing and/or possibly starting to grow AIVs increasing consumption to improve health.

- We are tracking the nutrient content of the AIVs grown locally, and identifying those which are rich sources of vitamins and minerals.

- We are now tracking 1,000 households (500 in Kenya; and 500 in Zambia) and separating them into different treatment groups mentioned, will allow us to better understand what drives individuals to purchase and consume more AIVs and/or to grow their own.
Acknowledgements & Our Horticultural Nutrition R&D Team:

Led by Rutgers University and Purdue University:

Jim Simon, PI, Rutgers, Horticulture, Breeding, Natural Products and Nutrition
Steve Weller, co-PI, Purdue, Horticulture/Production Systems
Dan Hoffman, co-PI, Human Nutrition, RU
Ramu Govindasamy, co-PI, Economics, Marketing, Consumer studies, RU
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Qingli Wu, Chemistry, Pharmagnosy and phytochemistry of AIVs, RU
Xenia Morin, Gender and development, RU
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WorldVeg Center: Marco Wopereis

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