Exploiting the diversity of African vegetables for improved nutrition Agenda for plant breeders

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Outline

- Food and nutrition security and SDGs
- Diversity in traditional vegetables, diversity of nutrients
- Past programs and projects on African traditional vegetables
- Current research and development challenges
- Research avenues for plant breeders
- Way forwards
- Further readings





Household economic stability for SDGs attainment



Household economic stability for SDGs attainment

State of Nutrition in a snapshot (2016)

Indicator	Number	Share of the reference population
Children under 5 who suffer from stunted growth	154.8 million	22.9 percent
Children under 5 affected by wasting	51.7 million	7.7 percent
Children under 5 overweight	40.6 million	6 percent
Adult obesity	640.9 million	12.8 percent
Women of reproductive age affected by anaemia	613.2 million	32.8 percent
Infants younger than 6 months exclusively breastfed	60.3 million	43 percent





Household economic stability for SDGs attainment



Source: United Nations Population Division. Data after 2011 are projections.

Africa rural and urban population (1960-2050)

- A dynamic disparity between rural and urban population growth!
- Consequence: more production for cities!!! Reduced wild harvest!







Household economic stability for SDGs attainment

- SDG 2: "End hunger, achieve food security and improved nutrition and promote sustainable agriculture".
- SDG 3: "Ensure healthy lives and promote well-being for all at all ages"
- According to Geargieff et al (2018: Acta Pedriatica) "

"Optimizing nutrition during foetal and early postnatal life is a golden opportunity to impact neurodevelopment and brain function across the lifespan."





Food and nutrition security in vulnerable populations

- Smart nutrients supply = smart brain development
- Nurture and Nourish! Fundamental functions of healthy parents!
- Iron, Iodine, Vit B12, Zinc: recognized for their role in brain development

Iron assessment to protect the developing brain

Michael K Georgieff

Division of Neonatology, University of Minnesota School of Medicine and University of Minnesota Masonic Children's Hosp

ABSTRACT

Iron deficiency (ID) before the age of 3 y can lead to long-term neurological deficits despite prompt diagnosis of ID anemia (IDA) by screening of hemoglobin concentrations followed by iron treatment. Furthermore, pre- or nonanemic ID alters neurobehavioral function and is 3 times more common than IDA in toddlers. Given the global prevalence of ID and the enormous societal cost of developmental disabilities across the life span, better methods are needed to detect the risk process throughout development, with successful completion of the previous s development early in life sets the stage and more efficient brain in adulthood. scaffolding process makes it imperative that are necessary for normal brain deve remedied early. In turn, this relies on a bioindicators (4) that index brain tissue



Thinkers of today, achievers of tomorrow

Oréofè A.D





Diversity of traditional vegetables, diversity of nutrients

SMOAD

No traditional vegetables left behind





Diversity of traditional vegetables, diversity of nutrients



Families

Nutraceutical utilization of African traditional vegetables



Rich in bioactive compounds like phenolic compounds, flavonoids, carotenoids, and anthocyanins.

These compounds are known to have anticancer, antiviral, antitumour, antimicrobial and antioxidant activities;

(Akakpo & Achigan-Dako 2019, Agronomy: 9, 805)





Nutraceutical utilization of African traditional vegetables

Potential application of phenolic compounds from vegetables



(Dias et al 2020, Critical reviews in Food Science and Nutrition)





Past programs and projects on African traditional vegetables

Traditional African Vegetables: Directory of Research and Development Specialists

Neglected leafy green vegetables in Africa. Vol. 1



Traditional African Vegetables: Directory of Research and Development Specialists Introduction In 1995 IPGRI organised the first international workshop on "genetic resources of traditional Vegetables in Africa: conservation and use" at the ICRAF Headquarters, Narobi from 29 - 31 August. In the final plenary session of the the following points were made: It was decided that some kind of network on African traditional vegetables would serve a useful purpose. However, it was thought necessary to first develop a list of exasting relevant activ Traditional African Vegetables: Directory of Research and Development Specialists Ac lishe ٠ TPG **Reference** List IPG 1. Oliweya, J. A. and N. A. Muzava. 1997. Cat's whishers. Clinine genanandra L. Promising the Conservation and Use of Underufilized and Neglected Crops. 11: Institute of Plant Genetics and Crop-Plant Research, Gaterleben/International Plant Genetic Resources Institute, Rome, Italy, 2 Edmonds, J. M. and J. A. Chweys, 1997. Black nightshades. Jalanan agram L. and related species. Promoting the Conservation and Use of Underutilized and Neglected Crops, 15.: Institute of Plant Genetics and Grop Plant Research, Gaterleben/International Plant Genetic Resources Institute, Rome, Italy. 3. Cmanno, L. 1997, Traditional African Vegetables. Proceedings of the IPGRI International Workshop on Genetic Resonances of Traditional Vegetables in Africa: Conservation and use, 29-31 August 1995. ICRAF-HQ, Nurobi, Kenya: Promoting the Conservation and Use of Underunlized and Neglected Coops 16: Institute of Plant Genetics and Coop Plant Research, Gatersleben/International Plant Genetic Resources Institute, Rome, Italy, 4. Schippers, R. and L. Budd. 1997. Workshop on African indigenous vegetables Limbe Cameroon, January 13-18, 1997 Workshop papers. CIDA:

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Vegetables / Légumes: 396 species



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Pilot projects: vegetables

- Farmer-participatory promotion –of spider plant (*Cleome gynandra*),
 - –African nightshade (Solanum scabrum) and
 - –Amaranth (Amaranthus hybridus) production.

 The Kenya agricultural research institute (KARI) in Maragwa District, Central Province, Kenya (June 2006 - August 2007)









Past and current programs and projects: INDIGENOVEG

INDIGENOVEG (Networking to promote the sustainable production and marketing of indigenous vegetables through urban and peri-urban agriculture in sub-Saharan Africa) – Jan 2006 to Jan 2008.

Objectives

- Co-ordinate & link existing research efforts on IVs & UPA by creating a forum where partners can share information
- 2) Develop relevant, targeted, research proposals
- Disseminate the outcomes of 1&2

Activities

- 1) sharing and discussing recent and on-going research findings
- collecting background information to start filling in knowledge gaps on indigenous vegetables (IV) in urban and peri-urban agriculture (UPA)
- 3) identifying directions for future research
- 4) networking and engaging with a wider audience of scientists, policy makers and farmers.



Past and current programs and projects: INDIGENOVEG



African Indigenous Vegetables in Urban Agriculture

Edited by Charlie M. Shackleton, Margaret W. Pasquini and Axel W. Drescher





Pamphlets on cultivation techniques and recipes for Amaranthus spp., Brassica carinata, Cleome gynandra, Hibiscus sabdariffa, Abelmoschus esculentus, Cucurbita moschata, Solanum aetiopicum, Solanum scabrum, and Corchorus olitorius.







Recipes for Success

Enhancing productivity and consumption of indigenous horticultural food crops for better nutrition and health through enhanced communication of research results in communityrun resource centres.







Darwin Initiative Project

- Title: Conservation of Biodiversity in Traditional West African Species
- Objective: improving the conservation and sustainable use of biodiversity in Mali and Benin
- Partners: INRAB (Benin), IER (Mali), University of Wales Bangor (UK)







Past and current programmes and projects: MicroVeg

- Funding: Canadian International Food Security Recsearch Fund (CIFSRF).
- Title: Scaling-up synergized indigenous vegetables and fertilizer microdosing innovations.
- Species: Telfairia occidentalis Hooke, Solanum macrocarpon and Amaranthus spp.
- Countries: Benin, Nigeria.







Past and current programs and projects: CLEONOMICS

- Goal: to develop improved cultivars of spider plant for Benin and Kenya markets.
- **Consortium:** FSA/UAC, KENRIK, WUR, World Vegetable Center, NGO Hortitechs developpement.







SAFEVEG: Safe locally-produced vegetables for West Africa's consumers

- Aims: to create a vegetable sector innovation axis that will allow for expansion to other countries in the Economic Community of West African States (ECOWAS)
- Consortium: World Vegetable Center, CIRAD (France), Wageningen University (Netherlands), INERA, IER, INRAB
- Countries: Burkina Faso, Mali, Benin
- Donors: European Union, Netherlands.



Copyright: World Vegetable Center





Current research and development challenges

- R&D programs still limited to a few countries or crops
- Lack of statistics (national, regional, international)
- Lack of scientific knowledge
- Insufficient production for industries
- Limited access to quality seeds by the majority
- Erosion of local knowledge in youth
- Overall neglect by mandatory institutions...





Current research and development drivers

- 1. Developing market and value chains for African vegetables.
- 2. Creating conducive home gardening strategy for increased consumption of fresh products.
- 3. Intensifying transition to agro-ecological production of African vegetables in urban and peri-urban areas and circular economy.
- 4. Generating accurate statistics for informed policy development and decision making.
- 5. Designing technologies to upscale low-cost production and processing of African vegetables.





Market and value chains development: adding value to primary products

The Farmer Development Chain for organic micro farming projects

Originated and developed by Rob Small for Abalimi Bezekhaya and the Farm & Garden National Trust





Crop husbandry and developing best cultivation practices for increased production

- Moving beyond the contemplation....
- Assessment of farmers practices for cultivation of the indigenous leafy vegetables.
- Field evaluation of best farmer's practices of the indigenous leafy vegetables.
- Farmer's field school to facilitate adoption of innovations.







Home gardening strategy for sustainable utilization



Source: Gbedomon et al. 2016. Scientia Horticulturae

Fig. Different spatial configurations of home gardens: (a) = back yard; (b) front yard; (c) fence; (d) shower margin; (e) wall margin; (f) jar margin; (g) = pots;





Home gardening strategy for sustainable utilization

- 1. Genetic diversity conservation
- 2. All time availability of fresh vegetable products for consumption
- 3. Increase income generation for farmers especially women
- 4. Better integrated crop management







Transition to agroecological systems



Tapsoba et al. 2020. Agronomy 10, 1447





Statistics of vegetable production in Africa

Timeseries on selected data

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Designing technologies to upscale low-cost production and processing of African vegetables

Constraints include:

- inadequate electricity supply,
- use of inappropriate technology, inadequate working capital,
- high interest rates,
- limited access to banks and other financial institutions











Research avenues for plant breeders

- 1. understanding the **reproductive biology** and mating systems that increase genetic gains,
- inventory of available genetic resources and re-assessing genepool and germplasm for additional collections to increase geographical coverage;
- **3. phenotyping and genotyping** of germplasms for added value traits;
- **4. genomic selection and molecular breeding** of cultivars to increase accuracy and reduce selection cycle;
- 5. multi-environmental testing and end-users' evaluation;
- 6. setting up quality **seed system sectors**.





Model of an integrated breeding program for traditional vegetables



Sogbohossou et al. 2018. Hort Research 5(2).

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Case study: Gynandropsis gynandra







Phenotyping: Morphological variation in *G.* gynandra



Phenogram based on qualitative and quantitative descriptors





Phenotyping: analysis of genes actions



The genetic gain equation and its components

variables (Moose & Mumm 2008).





Correlation between morphological traits and nutrients



Positive correlation between:

- -Carotenoids
- -Foliar traits
- -Floral traits
- -Carotenoids and floral traits
- -Carotenoids and foliar traits
- -Carotenoids and plant height

(Sogbohossou et al. 2019: Planta)

Correlation heatmap for morphological traits and nutrients





Planta https://doi.org/10.1007/s00425-019-03142-1

ORIGINAL ARTICLE



Association between vitamin content, plant morphology and geographical origin in a worldwide collection of the orphan crop *Gynandropsis gynandra* (Cleomaceae)

E. O. Dêêdi Sogbohossou^{1,2} · Dieke Kortekaas¹ · Enoch G. Achigan-Dako² · Patrick Maundu³ · Tsvetelina Stoilova⁴ · Allen Van Deynze⁵ · Ric C. H. de Vos⁶ · M. Eric Schranz¹¹



8-fold variation in vitamin C content



Accessions



5

Alphacarolene (ug/g)

- 4

15 20 25 20 35

Belacarolene (ug/g)



936 leaf semi-polar metabolites detected in the leaves of 48 accessions off G. gynandra



Sogbohossou et al. 2020 (Phytochemistry: 178)



Genomics resources for breeding



Venn diagram illustrating the shared and unique gene families from *Gynandropsis gynandra*, Tarenaya hassleriana (Cleomaceae), Arabidopsis thaliana and Brassica rapa (Brassicaceae). The number of genes in shared gene families are in parentheses

(Sogbohossou 2019.)





Genomics resources for breeding



Resequencing analysis of seven Amaranthus accessions. (A) Venn diagram of the intraspecific single nucleotide polymorphisms (SNPs) identified in the A. hypochondriacus accessions. (B) Venn diagram of the interspecific SNPs identified among A. hybridus, A. cruentus, and A. caudatus. The number of identical SNPs between accessions is shown. (C) Unrooted neighbor joined tree showing the relationship of the seven resequenced accessions of amaranth based on all SNPs.

(Clause et al. 2016; The Plant Genome 9(1))





Setting up quality seed system sectors



Mechanisms underlining dormancy and seed germination control in plants. Highlights of Abscisic and gibberellic acid metabolism and signaling pathways.



(Sohindji et al 2020: Agronomy 10, 57)





Way forwards

- Rethinking the promotion for increased consumption
- Youth involvement in awareness raising: hope for traditional vegetables
- Awareness campaigns among pupils: school's restaurant
- Novel food products and by products:
 - Moringa cake
 - Ocimum ice tea
 - Amaranthus infant flour
 - Amaranthus biscuit

• Increased consumption is a driver of production!





Further readings

- Sogbohossou E.O.D, Achigan-Dako E. G., Mumm R., de Vos, R. and Schranz E., 2020. Natural variation in specialised metabolites production in the leafy vegetable spider plant (*Gynandropsis gynandra* L. (Briq.)) in Africa and Asia. Phytochemistry 178, 112468. <u>https://doi.org/10.1016/j.phytochem.2020.112468</u>
- Blalogoe, Jelila S., Alfred O. Odindo, EO Dêêdi Sogbohossou, Julia Sibiya, and Enoch G. Achigan-Dako.
 « Origin-dependence of variation in seed morphology, mineral composition and germination percentage in Gynandropsis gynandra (L.) Briq. accessions from Africa and Asia. » *BMC Plant Biology* 20, no. 1 (2020): 1-14
- Sohindji, F.S.; Sogbohossou, D.E.O.; Zohoungbogbo, H.P.F.; Houdegbe, C.A.; Achigan-Dako, E.G. Understanding Molecular Mechanisms of Seed Dormancy for Improved Germination in Traditional Leafy Vegetables: An Overview. Agronomy 2020, 10, 57
- Akakpo AD.M. and Achigan-Dako. E.G. 2019. Nutraceutical Uses of Traditional Leafy Vegetables and Transmission of Local Knowledge from Parents to Children in Southern Benin. Agronomy 9 (12), 805, 2019.
- Sogbohossou E.O.D, D. Kortekaas, E.G. Achigan-Dako, P. Maundu, T. Stoilova, A. Van Deynze, R.C.H. de Vos, M. E. Schranz. Association between vitamin content, plant morphology and geographical origin in a worldwide collection of the orphan crop *Gynandropsis* gynandra (Cleomaceae). Planta. <u>https://doi.org/10.1007/s00425-019-03142-1</u>
- Zohoungbogbo, H.P., C.A. Houdegbe, D.E. Sogbohossou, M.G. Tossou, P. Maundu, E.M. Schranz, et al. 2018. Andromonoecy in *Gynandropsis gynandra* (L.) Briq.(Cleomaceae) and effects on fruit and seed production. <u>Genetic Resources and Crop Evolution</u> 65: 2231-2239.
- Houdegbe, C.A., E.D. Sogbohossou and E.G. Achigan-Dako. 2018. Enhancing growth and leaf yield in *Gynandropsis gynandra* (L.) Briq.(Cleomaceae) using agronomic practices to accelerate crop domestication. <u>Scientia Horticulturae</u> 233: 90-98.





Thank you for your kínd attentíon!

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