Health-promoting attributes of underutilised African legumes

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Global Climate Change

- Average temperature increase
- Rising atmospheric CO₂ concentrations
- Change in climatic variability and extreme events
- Change in rainfall amount and patterns
- Pollution levels increase (tropospheric ozone)
Projected impact of climate change on agricultural yields

A key culprit in climate change — carbon emissions — can also help agriculture by enhancing photosynthesis in many important crops such as wheat, rice, and soybeans. The science, however, is far from certain on the benefits of carbon fertilisation.

This map represents the case of beneficial carbon fertilisation processes.

Source: Ollie W., 2007, Global Warming and Agriculture.

European Environment Agency, 2015
The African Problem – Malnutrition and Obesity

Drivers
- Urbanization
- Rising incomes
- Poor dietary choices due to need for convenience (high in saturated fat, sugar, refined foods, low in fibre)
- Low levels of physical activity

Nutrition Transition

Malnutrition

Obesity

Metabolic syndrome
- Cancer
- Cardiovascular disease
- Type II diabetes
Meeting the challenges

Food Crops

Drought tolerant

Low water footprint

Nutritious

Health promoting

Climate-smart African Legumes
Climate-smart African Legumes

Cowpea
(Vigna unguiculata)

Bambara groundnut
(Vigna subterranea)

Marama bean
(Tylosema esculentum)
Drought tolerance and water footprint

• All three legumes are drought-tolerant
• Cowpea and Bambara groundnut can also withstand water logging
• Cowpea and Bambara groundnut are well adapted to rain-fed agriculture systems of the Sahel and Savanna regions
• Low water footprint for grain and protein production
• Creeping marama vines die in winter. But the plant is maintained by storage roots or tubers that can contain high amounts of water – an emergency water source for the arid, desert region of the Kalahari
Cooked cowpeas

Uncooked cowpeas

Acetone extraction

Simulated in vitro GIT digestion

Acetone extracts

Enzyme digests

Analyses

Phenolic composition (LCMS)
LDL oxidation
Inflammation biomarkers (gene expression)
Induction of NQR (Phase II enzyme)
Inhibition of cancer cell proliferation
Phenolic composition

Phenolic acids
- Coumaric acid and derivatives
- Ferulic acid and derivatives
- Protocatechuic acid

Cowpeas

Flavan-3-ols
- Catechin
- Epicatechin
- Oligomeric procyanidins

Flavonols
- Quercetin and glycoside derivatives
- Kaempferol and glycoside derivatives
- Myricetin and glycoside derivatives
Effect of Glenda cowpea extracts on copper catalyzed in vitro human LDL oxidation using TBARS assay. Error bars are standard deviation. Bars with different letters are significantly different (p<0.05)
Effect of Agrigold cowpea extracts on copper catalyzed in vitro human LDL oxidation using TBARS assay. Error bars are standard deviation. Bars with different letters are significantly different (p<0.05)
Mechanism of inhibition of LDL oxidation

• Scavenging of free radicals formed during lipid oxidation by antioxidant phenolics

• Chelation of copper ions which catalyse the LDL oxidation process especially by phenolics with the catechol structure

[Chemical structures of Quercetin and Protocatechuic acid are shown in the diagram]
Cancer
Pulmonary diseases
Neurological diseases
Autoimmune diseases
Reactive Oxygen Species

Inflammation e.g. NF-κB, COX-2
Cardiovascular diseases
Weak Immune System
Diabetes II

Arthritis

Bioactive compounds (e.g. phenolics) can modulate cellular processes to provide protection against non-communicable diseases
Effect of uncooked Agrigold and Glenda cowpea extracts on the gene expression for tumor necrosis factor (TNF) α by Human umbilical vein endothelial cells
Effect of cooked Agrigold and Glenda cowpea extracts on the gene expression for tumor necrosis factor (TNF) α by Human umbilical vein endothelial cells
Effect of cooked Agrigold and Glenda cowpea enzyme digests on the gene expression for tumor necrosis factor (TNF) α by Human umbilical vein endothelial cells

Gene expression for TNF-α

Cooked Agrigold cowpea enzyme digest

Cooked Glenda cowpea enzyme digest
Phenolics and inflammatory biomarkers

- Phenolics can inhibit enzymes involved in cell signalling pathways that lead to inflammation. As a result, inflammation biomarkers may be reduced.
- Overall, Agrigold cowpea seemed to be more effective at reducing gene expression for inflammation biomarkers than Glenda.
- May be related to differing phenolic composition e.g. presence of dihydroquercetin (taxifolin) and its glycoside in Agrigold but not in Glenda.

![Taxifolin](image1.png)

![Taxifolin glucoside](image2.png)
Foreign pre-carcinogen compounds

Highly reactive molecules (Carcinogenic, toxic)

Phase I enzymes

Damage to proteins, RNA, DNA in cell (Cancer)

Phase II enzymes

Attack carcinogens
Render inert
Remove from body
NAD(P)H:quinone oxidoreductase (NQO) activity of Agrinawa (red cowpea type) extracts (relative to 0.1% DMSO control) in Hepa1c1c7 murine hepatoma cells *in vitro*. Bars and error bars represent means ± SEM of two separate determinations.
Phenolics and induction of NQO activity

• Raw and cooked Agrinawa induce NQO activity but not the enzyme digest
  – More phenolic compounds identified in raw and cooked Agrinawa compared to enzyme digest [no phenolic acids, three flavan-3-ols (out of seven) and eight flavonols (out of fourteen) were identified in enzyme digests]

• Lower levels of phenolic compounds in enzyme digests compared to raw and cooked Agrinawa
Inhibition of Caco-2 Cell Proliferation

![Graph showing inhibition of Caco-2 cell proliferation](image)

- Extract of raw Agrinawa
- Extract of cooked Agrinawa
- Enzyme digest of cooked Agrinawa

- Extract of raw Black-eye
- Extract of cooked Black-eye
- Enzyme digest of cooked Black-eye
Phenolics and cancer cell proliferation

• Overall better ability to inhibit cancer cell proliferation by Agrinawa cowpea compared to Blackeye
  – Possibly due to higher content of procyanidin dimers in Agrinawa compared to Blackeye

• Blackeye cowpea extracts despite being low in tannins, still inhibit cancer cell proliferation
  – Other phenolics apart from procyanidins may inhibit cancer cell proliferation
Cowpea seed coats

Extraction

Extracts
(1% HCl-MeOH, 80% Aq MeOH, Water)

Inhibition of alpha-amylase and alpha-glucosidase

Potential anti-diabetic properties
DR SAUNDERS

Flavanols  | Flavonols  | Flavanonols  | Flavones  | TOTAL
---|---|---|---|---
1% HCL-MEOH | 3736 | 2026 | 26 | 12 | 5800
80% AQ MEOH | 2784 | 269 | 0 | 8 | 3061
WATER | 2415 | 278 | 0 | 8 | 2701
AGRIGOLD

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ALPHA AMYLASE INHIBITION

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ALPHA GLUCOSIDASE INHIBITION

- 1% HCl-MeOH
- 80% Aq MeOH
- Water

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| OH groups attached to B ring (Catechol structure) | Hydrogen-bonding: with COOH-groups of amino acid residues (Lo Piparo et al 2008)  
Ionic interactions: With NH-groups of amino acid residues (Papadopoulou et al 2004) |
| 2,3-Double bond in the C-ring | Hydrophobic interactions: between polyphenol aromatic ring and hydrophobic amino acid residues (Papadopoulou et al 2004)  
Conjugation of C2-C3 double bond to 4-oxo-group enables conjugated π-system with amino acid residues which stabilizes the flavonoid-enzyme interaction in the enzyme active site (Lo Piparo et al 2008) |
Bringing African legumes to the dinner table

• Intensify efforts to educate consumers about the health benefits of legumes
• More research is needed, particularly human studies to increase knowledge base concerning health benefits of legumes
• Make legume products e.g. legume flours etc more available
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