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Moringa oleifera as Africa's green gold for a circular bioeconomy

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Moringa oleifera (moringa) is a tree from the Moringaceae family, originally from the southern foothills of the Himalaya Mountains, and currently grown in various tropical and subtropical parts of the world, including Africa. It is well known as an agroforestry tree and has adapted to growing in harsh conditions. It produces a high amount of biomass in a short period and contains high levels of nutrients and biologically active components. The tree has multiple uses and has the potential to open new business opportunities.

Core concept

Moringa oleifera is a versatile, fast-growing tropical plant uses and that can be transformed into multiple high-value streams – natural antioxidants, vitamins, proteins, coagulants, and livestock feed – through careful cultivation, optimized extraction, and cascading biomass use. The narrative embodies **circular bioeconomy principles**: maximizing resource efficiency, minimizing waste, conserving the environment, and generating multiple co-products from moringa based feedstocks (Figure 1, next page).

Resource efficiency & cascading use

Antioxidant extraction

A low-cost, mild process (aqueous ethanol at 30 °C for ~40 min) to extract antioxidant-rich fractions (ARF) from moringa leaves is available, for use in African situations. The resulting extracts matched or surpassed synthetic antioxidants (butylated hydroxytoluene (BHT), ethoxyquin, ascorbic acid) in radical scavenging potential and remained stable over several months. The ARF has applications in cosmetic industry, food industry and animal feed industry, including enhancing shelf-life of fishmeal, as an alternative to ethoxyquin which has been banned.

Residue upcycling as animal feed

Instead of discarding post-extraction biomass, the residue - ~42% crude protein, rich in essential amino acids could be repurposed as livestock feed including fish feed. Feeding trials suggested cost savings of 20-35% versus soymeal or fishmeal and a potential reduction in enteric methane emissions.

Cascading biomass use

A "cascading use" as a way to improve economic viability and sustainability is stressed: first extracting high value bioactives (polyphenols, vitamins, glucosinolates proteins) from leaves, then utilizing the remaining biomass as feed, fertilizer, or for energy recovery. While moringa seeds could be exploited for isolating flocculants (as a substitute for alum) for purification of drinking water in remote African locations. Moringa seed peptides, having highly positive charge, have been shown to decrease methane emission from, and proteolysis in, the rumen. Moringa peptides being anti-microbial also have potential as a growth promoter (at ppm levels), as an alternative to antibiotics in monogastric animals including fish. This layered approach aligns with the global circular bioeconomy frameworks.

Cultivation and accessions

Future demands building a reliable feedstock.

High productivity

Leaf yields of ~5 - 8 tons dry matter ha^{-1} $year^{-1}$ under high-density planting; pod yields up to 98 t fresh mass ha^{-1} $year^{-1}$ in improved varieties (PKM-2).

Nutritional variability

Protein, amino acid, and glucosinolate content vary with cultivar, plant part, harvest time, and environment.

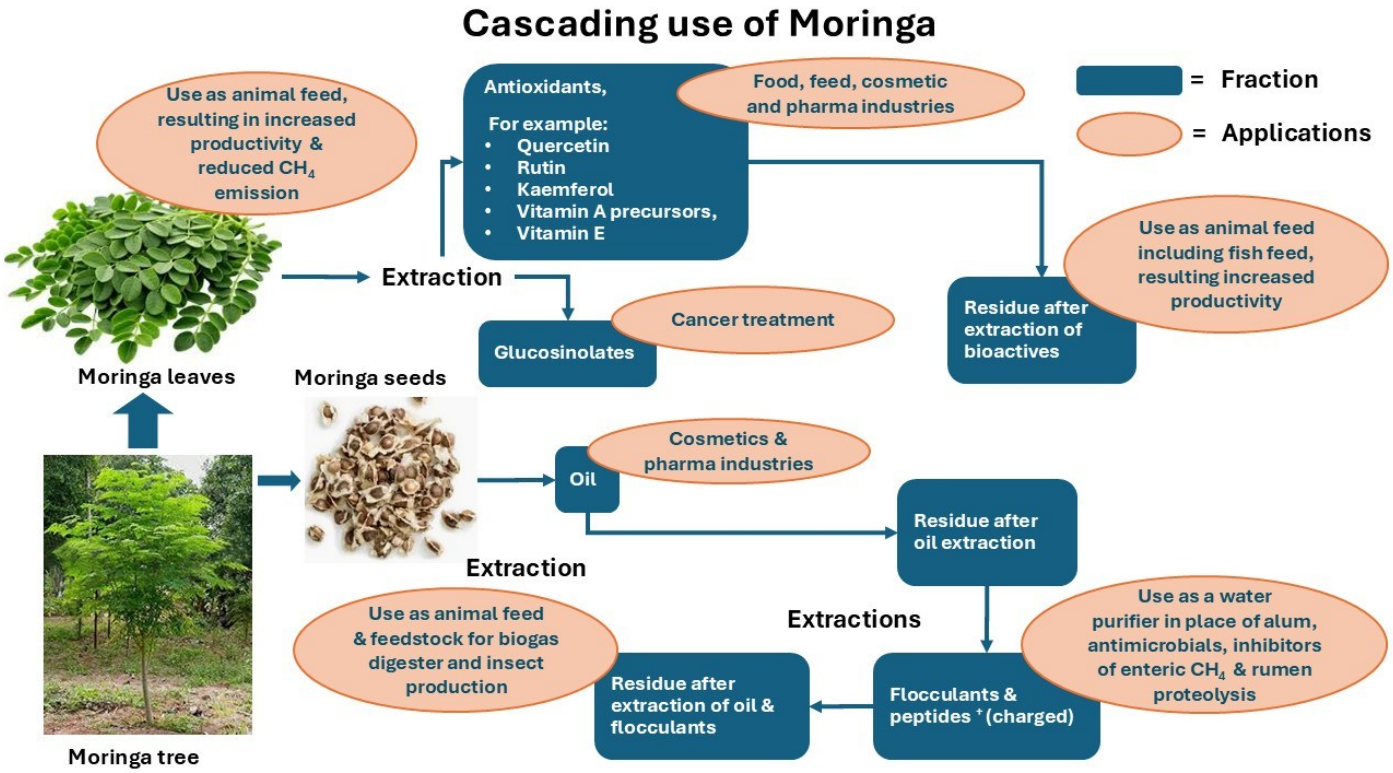

Figure 1. Cascading use of Moringa

Socio-economic fit

Moringa is already a staple for smallholders in India and Africa. Scaling its cultivation for leaf biomass and nutraceutical applications can empower women and Small and medium enterprises (SMEs).

Extraction and processing innovations

The extraction conditions (solvent type, temperature, pH, pre-treatments) strongly influence protein and bioactive yields. Batch to batch variations in leaf and seeds is another variable that must be minimized for successful business development.

- Mild, "green" extraction technologies (enzyme-assisted, ultrasound, aqueous buffers) to replace harmful organic solvents.
- Integrated process design so that conditions used for the first extraction step preserve the nutritional value of the residual biomass for subsequent uses (feed or fertilizer).
- Mapping of the bioactivities in the feedstocks obtained from the region of business operation, so that informed decision can be taken to strategically use the feedstocks obtained from different soils and environmental conditions, even following the same cultivation and management conditions.

Environmental and climate benefits

Substitution effects

Natural antioxidants reduce demand for petrochemical-derived additives; high-protein residue offsets soymeal and fishmeal, reducing land and marine pressure.

Lower emissions

Feeding moringa residues can mitigate ruminant methane emissions, contributing to climate goals. Other parts of the plant could also enhance animal productivity and lower carbon footprint.

Land use efficiency

Can be cultivated on marginal or suboptimal soils to avoid competition with food crops.

Governance and fair access

Transparent sourcing and equitable benefit-sharing must be built into moringa-based circular value chains.

Integrated circular bioeconomy model

Overall, a three-stage circular system emerges:

- Sustainable cultivation of moringa on marginal lands with high-yielding cultivars.
- Green extraction of high-value antioxidants, vitamins, proteins, and glucosinolates using mild, low-energy processes.
- Residue valorisation as high-protein livestock feed, fertilizer, or energy substrate, natural flocculants, anti-microbials and feed additives.

This system creates a closed-loop supply chain with multiple outputs, local employment, and environmental benefits—an archetype of the circular bioeconomy.

Outlook

- Standardization of cultivation, analytics, and processing methods to ensure reproducible product quality.
- Investment in decentralized processing units for smallholder regions.
- Regulatory and market development for moringa -derived products.
- Further research on methane mitigation and life cycle assessments of moringa-based feed systems.

In essence, *Moringa oleifera* can be transformed from a traditional multipurpose plant into the backbone of a circular bioeconomy.

Further reading

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