

Global cassava production: Economic importance and challenges faced by indigenous farmers

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ABSTRACT

Cassava (*Manihot esculenta* Crantz) plays a crucial role in global food security, particularly in developing regions where it serves as a staple crop for millions of people. It is valued for its resilience to harsh climatic conditions, high caloric content, and adaptability to various soil types. However, cassava production faces challenges such as pests, diseases, and low genetic diversity, which threaten yield stability and sustainability. This study explores cassava's contribution to food security, its botanical and nutritional properties, as well as modern technological advancements in its cultivation. Traditional and modern breeding techniques, including genetic modification and biotechnology, are analyzed in terms of their impact on improving yield, disease resistance, and environmental sustainability. The study also examines the limitations of these approaches and recommends innovative strategies to enhance cassava production efficiency. By leveraging scientific advancements and sustainable farming practices, cassava can continue to support global food security efforts, particularly in regions vulnerable to food scarcity.

Keywords: Cassava; Food security; Biotechnology; Breeding techniques; Disease resistance

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Introduction

Cassava (*Manihot esculenta* Crantz) is one of the most important staple food crops worldwide, serving as a primary source of carbohydrates for millions of people, particularly in tropical and subtropical regions. Native to South America, cassava has spread across Africa, Asia and Latin America due to its adaptability to harsh environmental conditions, including drought, poor soil fertility and erratic rainfall patterns (FAO, 2022). Unlike many staple crops such as wheat and rice, cassava requires minimal agricultural inputs and can be cultivated on marginal lands where other crops fail, making it a critical food security crop (Burns *et al.*, 2022). Cassava is valued for its high starch content with its roots serving as main harvested component. The roots can be consumed in various forms, including fresh, dried or processed into flour, starch and ethanol.

Additionally, cassava leaves are rich in proteins, vitamins and minerals making them an important supplementary food source in many regions (Talsma *et al.*, 2022). Beyond its role in human consumption, cassava is also widely used as livestock feed and in industrial applications such as biofuel production, pharmaceuticals, and paper manufacturing, highlighting its economic importance (Aerni, 2019).

Despite its significance in global food security, cassava production is faced with numerous challenges, including susceptibility to pests and diseases, low genetic diversity, post-harvest losses, and poor mechanization in its processing (Egesi *et al.*, 2021). The most devastating diseases affecting cassava include Cassava Mosaic Disease (CMD) and Cassava Brown Streak Disease (CBSD), both of which significantly reduce yield and quality. In addition, traditional breeding techniques for cassava improvement have been slow and inefficient due to its long growth cycle and genetic complexity (Legg *et al.*, 2021). To address these challenges, modern technological

advancements such as genetic modification, marker-assisted breeding, and biotechnology-driven disease management strategies have been developed to improve cassava yield, resistance to pests and diseases, and nutritional quality (Jansson *et al.*, 2023). Genetic engineering techniques, for example, have been used to introduce virus-resistant genes into cassava varieties, reducing the impact of CMD and CBSD. Similarly, advances in molecular biology and tissue culture propagation have enabled the rapid multiplication of disease-free cassava planting materials (Okogbenin *et al.*, 2019).

However, despite these technological innovations, the adoption of improved cassava varieties and modern farming techniques remains slow, particularly in developing regions where smallholder farmers dominate production. Limited access to improved planting materials, lack of knowledge on modern cultivation practices, regulatory barriers to genetically modified crops, and socio-economic constraints continue to hinder the widespread adoption of these technologies (Nassarand Ortiz, 2019). This research aims to explore the critical role of cassava in global food security, with a particular focus on the technological advancements that have been made in its production and the challenges that persist. By examining traditional and modern breeding approaches, genetic modifications, pest and disease management strategies, and the limitations of existing technologies, this study seeks to provide insights into sustainable solutions for enhancing cassava productivity. Ultimately, this research will contribute to the broader discourse on food security and the need for innovative agricultural practices to meet the growing global demand for food in the face of climate change and population growth.

2. Organic, Inorganic and Chemical Components of Cassava

2.1 Proximate Composition of Cassava: Cassava is primarily composed of carbohydrates, with minimal amounts of protein and fat. The typical proximate composition of fresh and dried cassava roots was presented (Table 1) (Aerni, 2019). Cassava leaves contain higher protein levels (15–25%), making them an important source of supplementary nutrition in animal feed and human diets when properly processed (Talsma *et al.*, 2022).

Table 1. Proximate analysis of fresh and dry cassava tubers

Parameter	Compositions	
	Fresh Cassava Tuber (%)	Dried Cassava Tuber (%)
Carbohydrates	30.0 ± 5.0	85 ± 5.0
Protein	1.5 ± 0.5	2.0 ± 1.0
Fat	0.2 ± 0.1	0.55 ± 0.45
Fiber	1.5 ± 0.5	3.5 ± 1.5
Ash	0.75 ± 0.25	1.5 ± 0.5
Moisture Content	65.0 ± 5.0	10.0 ± 2.0

2.2 Phytochemical Composition of Cassava

Cassava contains several bioactive compounds, including:

- **Cyanogenic Glycosides (Linamarin and Lotaustralin):** These compounds can release hydrogen cyanide (HCN) when consumed raw, making processing methods such as fermentation, drying, or boiling essential to reduce toxicity (Burns *et al.*, 2022).
- **Phenolic Compounds:** Known for their antioxidant properties, which contribute to the plant's resistance against pests and diseases (Lebot, 2019).
- **Saponins and Alkaloids:** Present in small amounts and contribute to the plant's defense mechanisms against herbivores and pathogens (Ceballos *et al.*, 2021).

2.3 Mineral Composition of Cassava: Cassava roots and leaves contain essential minerals necessary for human nutrition (Table 2).

Table 2. Minerals composition of cassava and their causal agent

Mineral	Concentration (mg/100g)	Health benefits
Calcium	30 – 50	Bone health
Potassium	200 – 500	Muscle and nerve function
Magnesium	20 – 40	Enzyme metabolism
Phosphorus	20 – 50	Energy metabolism
Iron	0.5 – 2.5	Red blood cell formation
Zinc	0.1 – 0.5	Immune function

Some of the highlighted essential minerals include:

- **Calcium (Ca):** Important for bone health and metabolic functions (100–200 mg/kg dry weight).
- **Iron (Fe):** Vital for oxygen transport in the blood (5–20 mg/kg dry weight).
- **Potassium (K):** Regulates blood pressure and muscle functions (1000–2000 mg/kg dry weight).
- **Zinc (Zn):** Essential for immune function and enzymatic reactions (10–40 mg/kg dry weight).

Biofortification efforts have been introduced to increase the mineral content of cassava, especially in regions where micronutrient deficiencies are prevalent (Talsma *et al.*, 2022).

3.0 Traditional vs. Contemporary Methods for Cassava Cultivation

3.1 Traditional cultivation of cassava: Cassava cultivation has been practiced for centuries in tropical regions and is considered one of the oldest staple crops in many indigenous communities. Traditional methods of cultivation are often practiced in smallholder farming systems and focus on minimal intervention with natural environmental conditions. The procedure adopted by indigenous cassava farmers in the production and processing of cassava tubers was captured in Fig 1 below. The key aspects of traditional cassava cultivation include:

3.1.1 Land Preparation: Traditionally, cassava cultivation begins with clearing and preparing the land. Farmers typically use simple tools like hoes or machetes to clear vegetation. Unlike other crops, cassava does not require extensive soil preparation, as it can grow in poor, low-fertility soils with minimal chemical inputs (Ceballos *et al.*, 2021). However, a well-tilled, loose soil is preferred to facilitate the development of its tuberous roots.

3.1.2 Planting Method: Cassava is usually propagated by stem cuttings, which are selected from healthy, disease-free plants. The cuttings are approximately 20-30 cm in length and are inserted into the soil at an angle of 45°. They are typically planted in rows, with a spacing of 1 m between plants, though this can vary depending on soil fertility and environmental conditions. In traditional farming systems, cassava is often intercropped with legumes or other crops like maize, beans, or ground nuts to enhance soil fertility and provide additional sources of food and income (Alves, 2022).

3.1.3 Maintenance and Harvesting: Cassava requires minimal care once planted. Regular weeding, pest and disease monitoring, and occasional irrigation are common practices in traditional systems. The plant is typically left to grow for 8-12 months before harvesting, depending on the variety and local growing conditions. Traditional farmers may harvest cassava roots incrementally, removing them as needed to supply fresh roots for consumption. Root quality often varies depending on the

season, with drought periods resulting in smaller roots (El-Sharkawy, 2020). Traditional cultivation methods, while sustainable in many contexts, often face challenges such as low yields, susceptibility to pests and diseases, and labor shortages. As a result, more advanced techniques are being sought to improve productivity and address global food security concerns.

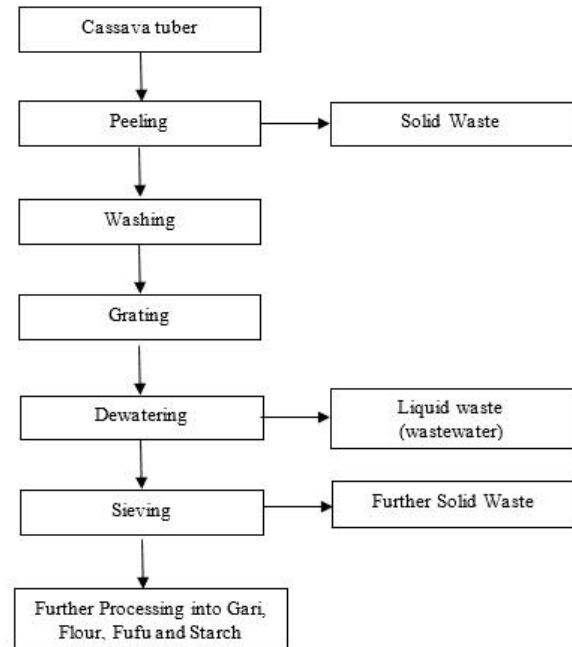


Fig. 1. Flowchart of cassava breeding process

3.2 Modern breeding techniques for cassava production: Modern breeding techniques for cassava aim to improve yields, pest and disease resistance, and nutritional content. With increasing demand for cassava as a source of food, animal feed, and industrial raw material, these advancements are critical for meeting the food security needs of growing populations. Key modern breeding approaches include:

3.2.1 Conventional Breeding: Conventional breeding involves selecting plants with desirable traits, such as high yield, pest resistance, or improved nutritional composition, and crossbreeding them to create hybrid varieties. The process can take several years, as cassava is a vegetatively propagated crop and must be carefully evaluated for traits in subsequent generations (Ceballos *et al.*, 2021). Hybrid varieties, such as the improved *Manihotesculenta* cultivars, have been developed to resist diseases like cassava mosaic disease (CMD) and cassava brown streak

disease (CBSD), which threaten cassava production worldwide (Legg *et al.*, 2021).

3.2.2 Marker-Assisted Selection (MAS): Marker-assisted selection (MAS) is a modern technique that accelerates the breeding process by identifying desirable genetic markers linked to traits of interest. In cassava, MAS has been used to develop varieties with enhanced disease resistance, improved drought tolerance, and higher starch content. MAS is often combined with conventional breeding methods to reduce the time needed to develop new cultivars with specific traits (Okogbenin *et al.*, 2019).

3.2.3 Genomic Selection: Genomic selection is an advanced breeding technique that uses genomic data to predict the performance of breeding lines based on their genetic makeup. This approach has proven effective in improving cassava's resistance to diseases like CMD and CBSD, which have had significant impacts on cassava production in Africa. By analyzing large datasets of genetic markers across cassava populations, genomic selection helps identify plants with superior traits early in breeding (Ceballos *et al.*, 2021).

3.2.4 Speed Breeding: Speed breeding is an innovative approach that aims to accelerate the breeding cycle through controlled environmental conditions, such as artificial light and temperature. This method reduces the time it takes to develop new cassava varieties, enabling breeders to test multiple generations in a short period. Speed breeding is particularly useful in accelerating the development of cassava varieties with improved disease resistance and drought tolerance, which are essential for ensuring food security in regions affected by climate change (Alves, 2022).

4.0 Cassava Breeding to Increase Yield and Disease Resistance: Genetic modification (GM) has emerged as a promising tool for improving cassava yields and making it more resilient to pests and diseases. Genetic engineering involves introducing specific genes into cassava's DNA to confer traits that would otherwise take years to develop through conventional breeding methods. Genetic modification of important food crop was, as a means for developing disease resistant varieties and improved yield plus physicochemical parameters, was also suggested by Etaware (2021) who examined the possibilities of genetic modification of cocoa to fight against the ravaging black pod disease

caused by the noxious pathogen "*Phytophthora* spp." (Etaware, 2019; Obiakara *et al.*, 2020; Etaware *et al.*, 2020; Etaware, 2021; Etaware, 2022; Etaware, 2023). Listed below are some of the benefits associated with breeding cassava for improved yield combined with resilience to diseases:

4.0.1 Increased Yield: Genetic modification techniques have been used to increase the starch content of cassava roots, thereby improving its yield potential. Transgenic varieties that produce higher levels of amylase (the enzyme responsible for breaking down starch) have been developed to ensure better utilization of available soil nutrients, ultimately leading to larger and more productive roots (Ceballos *et al.*, 2021).

4.0.2 Disease Resistance: Genetic modification has also been applied to improve cassava's resistance to viral diseases such as CMD and CBSD. Genetically modified cassava plants expressing resistance genes derived from other plants have shown improved resistance to these diseases, which are widespread in Africa, Asia, and Latin America. These GM varieties help mitigate the risk of crop loss due to disease outbreaks (Nassarand Ortiz, 2019).

4.0.3 Enhanced Nutritional Content: In addition to improving yield and disease resistance, genetic modification has also been used to enhance the nutritional content of cassava. Biofortified varieties of cassava are being developed to increase levels of essential micronutrients such as provitamin A, iron, and zinc. These biofortified varieties are particularly important in regions where cassava is a major dietary staple and deficiencies in these nutrients are prevalent (Talsma *et al.*, 2022). Despite these promising benefits, genetic modification of cassava has faced challenges, including regulatory hurdles, public perception issues, and the risk of genetic contamination. However, ongoing research and investment are expected to overcome these obstacles, helping GM cassava varieties reach commercial production.

4.1 Limitations of Traditional and Modern Breeding Methods: Both traditional and modern breeding approaches have made significant contributions to cassava production; however, they come with limitations:

4.1.0 Limitations of Traditional Breeding

- **Time-Consuming:** Traditional breeding methods rely on natural selection and can

take several years to produce desired traits in Cassava varieties.

- **Genetic Homogeneity:** Since cassava is propagated through stem cuttings (vegetative part), genetic diversity within commercial crops can be limited, making them vulnerable to pest and disease outbreaks.
- **Vulnerability to Climate Change:** Traditional methods have not adequately addressed issues related to climate change, such as increased drought or flood risks, affecting cassava's resilience (El-Sharkawy, 2020).

4.1.1 Limitations of Modern Breeding

- **High Cost:** Modern breeding techniques, such as MAS and genomic selection, require substantial financial investments in research infrastructure and labor.
- **Dependency on Technology:** Speed breeding and genomic selection rely on advanced technological tools that may not be accessible to all regions or farmers, particularly in developing countries.

Public Resistance to GMOs: Despite the potential benefits of genetic modification, the adoption of GM cassava faces challenges due to public concerns about safety and environmental impact (Lebot, 2019).

Recommendations: To improve cassava production and ensure its contribution to global food security, several strategies should be pursued:

1. **Promote Integrated Breeding Approaches:** Combining conventional breeding with modern techniques like MAS and genomic selection can expedite the development of new cassava varieties with improved disease resistance, higher yield, and enhanced nutritional content.
2. **Support Local Adaptation:** Breeding programs should focus on developing cassava varieties suited to local environmental conditions, particularly in drought-prone regions. This would reduce vulnerability to climate change and ensure more reliable harvests.
3. **Invest in Smallholder Farmers:** As cassava is primarily grown by smallholder farmers, policies that promote access to improved varieties, sustainable farming practices, and agricultural technologies are essential for

increasing productivity and addressing food insecurity.

4. **Increase Public Awareness:** Public education campaigns should be conducted to raise awareness about the safety and benefits of GM cassava, helping to address the resistance to GMOs.

Conclusions

Cassava is a vital crop in global food security, serving as a primary carbohydrate source for millions of people, especially in Africa, Asia, and Latin America. Despite its adaptability and resilience to challenging environmental conditions, its production faces significant constraints, including susceptibility to diseases, pests, and climate-related stressors. Traditional cultivation methods, while effective in certain regions, are often limited by low yields and prolonged growth cycles. Modern breeding techniques, including genetic modification, have provided promising solutions by enhancing cassava's disease resistance, increasing productivity, and improving nutritional value. However, these advancements come with challenges such as regulatory hurdles, public skepticism toward genetically modified organisms (GMOs), and the need for infrastructural support for smallholder farmers. To ensure sustainable cassava production, a holistic approach integrating traditional knowledge, biotechnology, and improved agronomic practices is essential. Governments, research institutions, and stakeholders must collaborate to promote cassava research, facilitate farmer education, and implement policies that support technological advancements in cassava farming. By addressing the existing limitations and leveraging scientific progress, cassava can continue to be a cornerstone of food security, particularly in regions facing food scarcity and agricultural challenges.

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