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Cassava Research in Ethiopia and Achievements: A Comprehensive Review

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***Abstract:** Cassava is a root crop cultivated mainly for its starchy roots, food stability and the most critical energy source root crop in tropics. In Ethiopia, cassava is grown in specific areas of the southern regions, offering several advantages over other cereals as a staple food in areas with poor soil conditions, uncertain rainfall, and limited market infrastructure. Despite research on crop adaptability, selection, nutritional, and anti-nutritional factors, there is a lack of information on the overall status, challenges, and the future role of cassava production in Ethiopia. This paper, therefore, aims to provide a brief overview of the genetic improvement, agronomic research, nutritional aspects, biochemical analysis, anti-nutritional factors, disease and insect pest management, and future research directions of cassava in Ethiopia. It highlights the description of cassava, its agroecology, and the contribution of cassava as both a food crop and a source of animal feed. Moreover, genetic improvement, agronomic research, nutritional, medicinal, and anti-nutritional research, harvesting, processing, utilisation, as well as cassava diseases and insect pests, are discussed. Since the inception of cassava research in Ethiopia, various research findings have been obtained and recorded, including the development of different varieties, agronomic practices, crop protection technologies, biochemical analyses for nutritional composition, and anti-nutritional factors. The availability of these outputs in a compiled and comprehensive manner is crucial for enhancing cassava production and productivity in Ethiopia, and for influencing policymakers to consider cassava as one of the prominent food and nutrition security crops in the country. Hence, the article can serve as a valuable reference resource for researchers, students, agricultural extension workers, and NGOs working in Ethiopia in root crops, particularly cassava.*

***Key words:** Breeding, Biochemical, Crop protection, Food security, Productivity, Technology*

I. INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is a dicotyledonous perennial shrub plant that belongs to family *Euphorbiaceae*. It is native to Brazil and was introduced to Africa by the Portuguese in the 16th century (FAO and IFAD, 2001 [32]; Andoh, 2010) [9]. Cassava is a root crop cultivated primarily for its starchy roots and food stability in the tropics, where it is the fourth most important source of energy.

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It is generally cultivated by small-scale farmers as a subsistence crop in a diverse range of agricultural and food systems (Alves, 2002) [6]. The success of cassava in Africa as a food security crop is mainly due to its ability to yield well in drought-prone, marginal wasteland under poor management, where other crops would fail. Cassava is a tropical root crop that requires at least eight months of warm weather to produce a crop. It is traditionally grown in a savanna climate, but can also be cultivated in areas with extreme rainfall. It is now extensively cultivated for consumption in tropical and subtropical regions (Burns *et al*., 2010) [15]. Cassava is known as an essential food security root crop for many African countries' smallholder farmers because of its wide adaptation to a variety of soil, climate, drought tolerance and generally, able to grow in challenging crop environments (FAO and IFAD, 2001 [33]; Misganaw and Bayou, 2020) [59]. In addition, its storage root is rich in carbohydrates, Calcium, vitamin B, vitamin C, and essential minerals (Alo *et al*., 2017) [4].

Cassava was believed to be exotically introduced to Ethiopia in the middle of the nineteenth century (Tassew, 2007), and it is currently grown in the southern part of Ethiopia and plays a vital role for consumption, animal feed and source of income to many rural and urban households (Tadesse *et al*., 2013). In Ethiopia, cassava is cultivated in some areas of southern regions. According to Feleke (1997) [31], cassava was introduced to drought-prone areas of the south part of the country, such as Amaro, Gamogofa, Sidama, Wolaita, Gedeo, and Konso, primarily to fill food gaps for subsistence farmers due to the failure of other crops resulting from drought. In these areas, farmers typically grow cassava in small, irregular, and scattered plots, either as sole crops or intercropped with taro, enset, maize, common bean, and sweet potato (Eyasu, 1997) [28]. According to Gebremedhin and Taye (2013) [36], the majority of the Ethiopian population relies on cereal crops as a primary food source, and the food potential of root and tuber crops has not been fully exploited and utilised, despite their significant contributions to food security, income generation, and providing food energy. However, cassava has several other advantages over other cereals, such as rice and maize, in areas with poor soil conditions, uncertain rainfall, and weak market infrastructure, making it a suitable food staple. However, researchers and policymakers have neglected cassava for numerous reasons, and it's also considered a staple food for people with low per capita incomes (Nweke, 2004). Despite research on crop adaptability, selection, nutritional, and anti-nutritional factors, there is a lack of information on the overall status, challenges, and the future role of cassava production in Ethiopia.

This paper, therefore, aims to provide a brief overview of the genetic improvement, agronomic research, nutritional aspects, biochemical analysis, anti-nutritional factors, disease and insect pest management, and future research directions of cassava in Ethiopia.

II. DESCRIPTION OF CASSAVA

Cassava is a perennial woody herb that is grown as an annual. Its name, cassava, is a collective name for many species belonging to the genus *Manihot* of the family *Euphorbiaceae* (Olsen and Schaal, 1999). Cassava is a small-branched woody herb that grows up to 5 m, with large, starchy roots. Its leaves are 3-5(-7) lobed (Gilbert, 1995) [37]. The genus *Manihot* belongs to the family Euphorbiaceae, with a chromosome number of 2n=36, and comprises approximately 100 species. Among these, *Manihot esculenta* is the only one commercially cultivated (Nassar, 1978; Alves, 2002 [6]; Ricardo *et al*., 2007). In Ethiopia, cassava is locally known by different names, such as "*Muka furno* (Oromifa)" ", *Yenchet boye* (Welayitigna)", "*Tesike/Mogo* (Koreegna)", "*Yefurno duket zaf*" (Amharic) and *Batata* (Somali) (Gilbert, 1995; Amsalu *et al*., 2000) [7]. The mature cassava plant (12 months old) contains 6% leaves, 44% stem and 50% tuber. The leaves are fingerlike, deeply indented, palmate 3-7 lobed, attached to a slender stem by long petioles. The flowers are small, greenish-yellow, occurring in panicles. The seeds are formed in capsules, which explode upon ripening to distribute their load (Aye, 2010) [11]. Stems, when planted, produce sprouts and adventitious roots within one week. Seeds usually are dormant and have slow germination rates. Seed dormancy does not break by scarifying the micropylar end; however, thermal treatment is the most effective, i.e., a temperature of 180 °C for 16 hours or 260 °C for 8 hours to achieve seed germination. Seedlings ensuing from sexual seed usually are weaker than those from cuttings (Nassar and Ortiz, 2007). Cassava cultivars are generally classified into two groups based on their hydrogen cyanide (HCN) content, with bitter cultivars producing as little as 20 milligrams of cyanide hydrogen (CN) per kilogram of fresh roots. In contrast, bitter ones may make more than 50 times more cyanide content (Dufour and Wilson, 2002) [21].

III. AGRO-ECOLOGY OF CASSAVA

Cassava is cultivated throughout the lowland tropics, typically between 30°N and 30°S of the equator, in areas where the annual mean temperature is greater than 180 °C. Generally, the crop tolerates a very hot climate, but it performs best where the mean temperature ranges from 25 °C to 30 °C. A critical temperature appears to exist between a daily temperature of 18-20°C, below which growth is reduced and yields decline rapidly, whereas at 10°C, growth ceases. Cassava grows very well in areas with a mean annual rainfall of more than 1000 mm. It is well adapted in areas with uniformly distributed rainfall ranging from 1000 to 3000 mm per year, as long as there is good internal drainage. Moreover, it can survive with as little as 500 mm of rainfall per year. Cassava cannot withstand flooding or prolonged periods of moist soil conditions, but it is tolerant of drought. When moisture availability is low, cassava plant ceases growth and sheds some of its older leaves. However, it resumes growth and produces new leaves when moisture becomes available (Bolhuis, 1966) [14]. Cassava is a sun-loving crop that requires a twelve-hour day length, which is reported to be optimal for cassava and can therefore be preferably grown under open conditions. Yield is drastically reduced under shaded conditions. Cassava tuberous root formation is controlled by photoperiod. Under short-day conditions, tuber formation occurs readily; however, at a day length of 12 hours, its growth is delayed, and yield is reduced. Cassava grows best on light, sandy loam soil of medium fertility with good drainage. On clay or poorly drained soil, growth is generally poor. Moreover, cassava can grow and yield well on soils of low fertility, where production of most other crops would be uneconomical. However, on highly fertile soil, cassava produces excessive vegetation at the expense of root formation. Hence, vegetative growth and leaf area of planted cassava cuttings approach a maximum within five months (Williams and Gazhali, 1969).

IV. CONTRIBUTION OF CASSAVA

A. Cassava as Food Crop

Cassava, with its starchy, swollen roots, is a major staple tuber crop in many tropical and subtropical developing countries, especially in West Africa. It is the third most important source of calories for populations in the humid tropics, after rice and corn (Zeigler *et al*., 1980; FAO, 2001). Cassava is grown in more than 90 countries and ranks fourth as a supplier of energy, after rice, sugar, and maize (Heuberger, 2005) [44]. The largest producing countries in Africa are Nigeria, Ghana, the Democratic Republic of the Congo, Mozambique, and Angola. In Ethiopia, cassava cultivation is predominantly found in the southern and southwestern parts of the country, primarily for its edible tubers (Amsalu et al., 2000). In Wolaita, southwest Ethiopia (Kefa, Bench, Maji, Sheko), and the Gambella areas, cassava tubers are consumed in the form of bread or injera by mixing their flour with different cereal crops (Amsalu and Elfinesh, 2006) [8]. Thus, cassava is a nutritionally strategic famine crop and could support food security in areas of low rainfall. The productivity of cassava on marginal soils, its ability to withstand diseases, drought, and pests, and its flexible harvesting dates make it a remarkably adaptable and hearty crop in areas where drought, poverty, and malnutrition are prevalent (Nassar *et al*., 2009). Mature tubers can survive for an extended period without water and still retain their nutritional value. Moreover, tubers are a valuable source of calories, whereas cassava leaves are a valuable source of protein, minerals and vitamins (Dufour and Wilson, 2002) [21]. Cassava roots can be stored in the ground for up to 24 months, and in some varieties, for up to 36 months. Thus, harvest may be delayed until market, processing, or other conditions are favourable.

B. Cassava as Feed Crop

Cassava is one of the most drought-tolerant crops and can be successfully grown on marginal soils, yielding reasonable yields where many other crops struggle. Both roots and leaves are suitable for use as livestock feed. Cassava offers tremendous potential as a low-cost source of feed energy for livestock, provided it is well-balanced with other nutrients. Its leaves are rich in protein, calcium, iron, and vitamins, comparing favourably with other green vegetables generally regarded as good sources of protein (Hahn, 1988) [42]. Thus, low-cost livestock feed resources, such as cassava, can be beneficial to smallholder farmers during the dry season when forage is scarce. The foliage of the cassava makes a significant contribution as fodder in our country. Cassava leaves can be harvested within 4 to 5 months of planting without adversely affecting root production and yielding up to 10 tons of dry foliage per hectare (Khajarern and Khajarern, 1992) [53]. Cassava chips have been used informally for animal feeding; however, despite their great potential in the domestic market, little research has been conducted, and neither private nor government feed processors are interested in incorporating cassava into their products.

C. Nutritional Value of Cassava

i. Cassava Tubers

Cassava tubers have a high concentration of carbohydrates, ranging from 80-90% on a dry weight basis, of which 80% is starch (Gil and Buitrago, 2006) [38]. They also contain small quantities of sucrose, glucose, fructose, and maltose (Tewe and Lutaladio, 2004). The nutritional composition of cassava tubers is depicted in Table 1. Tubers have very low quantities of lipids, minerals, proteins, and vitamins compared to the leaves. Thus, the tubers, which constitute 50% of the mature cassava plant, are the nutritionally valuable parts of cassava (Tewe and Lutaladio, 2004). Cassava tubers contain calcium, iron, potassium, magnesium, copper, zinc, and manganese, with contents comparable to those of many legumes, except for soybeans. The calcium content is relatively high compared to that of other staple crops, ranging between 15 and 35 mg/100 g edible portion. The vitamin C (ascorbic acid) content is also high, ranging from 15 to 45 mg/100 g of edible portions (Charles *et al*., 2005). Cassava tuber is an energy-dense food. In this regard, cassava shows very efficient carbohydrate production per hectare. It produces approximately 250,000 calories/hectare/day (Julie et al., 2009) [50], ranking it ahead of maize, rice, sorghum, and wheat. Cassava has bitter and sweet varieties. In the latter varieties, up to 17% of the tuber is sucrose with small amounts of dextrose and fructose (Charles *et al*., 2005) [17].

ii. Cassava Leaves

Cassava leaves are rich in iron, zinc, manganese, magnesium, and calcium; vitamins B_1, B_2, and C; and carotenoids (Wobeto *et al*., 2006). The shoots grow into leaves that constitute a good vegetable rich in proteins, vitamins and minerals. New knowledge of the crop's biochemistry has shown that the proteins embedded in the leaves are of equal quality to those found in eggs. Cassava leaves, if properly processed, can therefore provide a balanced diet that protects millions of African children against malnutrition (Taye, 2015). Cassava leaves also have excellent potential and are widely used in Africa and Asia, either as human food or animal feed. Its leaves, commonly eaten as a vegetable in parts of Asia and Africa, provide vitamins and proteins. All of these benefits made the crop a preferred choice for food and fodder, as well as a cash crop (Gil and Buitrago, 2006).

V. OPPORTUNITIES AND CONSTRAINTS OF CASSAVA PRODUCTION

A. Opportunities of Cassava Production

Cassava starch exhibits several remarkable characteristics, including high purity, excellent thickening properties, a neutral taste, desirable textural properties, and a relatively inexpensive source of raw material, making it a superior alternative to other starch source crops such as maize, wheat, sweet potato, and rice. The process of starch extraction is also relatively simple, which makes the processing of cassava starch particularly suitable for developing countries like Ethiopia. Moreover, the market for starch products can be increased by using starch as a biodegradable packaging material, in response to the world's concern about environmental issues. Hence, cassava is most widely grown to produce a sustainable and cheap source of starch globally (Singh *et al*., 2011). Since replacing non-biodegradable products can be a significant market worldwide, cassava-producing countries can capitalise on this opportunity. As a biofuel crop, cassava has the advantage that the root can remain in the ground for months without deterioration, allowing for carefully planned and continuous harvest schemes. The crop is also resilient to poor environmental conditions, such as low rainfall. Cassava roots are not as voluminous as sugarcane or sorghum stalks, and thus, they make it easier and cheaper to transport. Moreover, cassava is found to be the cheapest bio-crop, costing 30% less than sugar cane and 20% less than sweet sorghum. In line with this, it was reported that 34% of the country's land area is suitable for cassava cultivation. Hence, the country can produce up to 355.44 billion litres of biodiesel and 225.09 billion litres of bioethanol, respectively, by cultivating various potential feedstock crops (FAO, 2008) [34].

B. Constraints of Cassava Production

A prominent constraint in cassava roots as a human food source is the presence of toxic cyanogenic glycoside compounds in the tissues. The plant is famous for the presence of free and bound cyanogenic glucosides, linamarin and lotaustralin, which are converted to hydrogen cyanide (HCN) in the presence of linamarase, a naturally occurring enzyme in cassava (Wilson and Dufour, 2002; Haque and Bradbury, 2004). The amount of cyanide in the tuber is genotype dependent. All plant parts contain cyanogenic glucosides with the leaves having the highest concentrations. In cassava roots, the concentration of cyanogen increases from the insertion point on the plant to the root terminal in the longitudinal direction. In the transverse direction, cyanogen levels decrease from the external area to the centre of the root (Jennings, 1971) [49]. The presence of cyanogenic glucosides in cassava tissues is associated with various health disorders that occur in populations where cassava is a staple food. These disorders include tropical ataxic neuropathy, epidemic spastic paraparesis, also known as endemic goitre and cretinism. However, cassava cyanogens can be reduced to low levels through several cassava processing methods. When cassava is eaten in combination with other foods to balance its nutritional value, there is little danger of intoxication (Westby, 2002).

VI. CASSAVA RESEARCH IN ETHIOPIA

A. Genetic Improvement

In recent years, there has been progressive work on cassava crop improvement in various agro-ecological locations across the country. The first outperforming two cassava varieties (Qulle and Kello) were officially released in 2005 (MoA, 2005) [60]. To alleviate the problem and provide farmers with alternative varieties, the Hawassa Agricultural Research Centre, in collaboration with the Jimma and Sekota Agricultural Research Centres, as well as other research institutions, has been actively conducting crop improvement trials of cassava clones to identify high-yielding ones. Additionally, there have been reports on the development of protocols for the mass propagation of specific cassava varieties in Ethiopia. Dawit (2019) [23] reported on the in vitro propagation of cassava varieties through meristem culture, developing an efficient in vitro mass propagation protocol for elite cassava clones using nodal segments. The improvement work was primarily achieved through the introduction, evaluation, and selection of germplasm, focusing on the best-yielding varieties that are resistant to disease and insect pests. The collection of locally available cassava germplasm and the selection of the best genotypes is the second approach being practised by the cassava improvement program scheme. The third approach, crossing and evaluation of progenies for various traits, which is still in its infancy, is less practised in Ethiopia until recently. Results have been obtained with breeding approaches where six varieties have been officially released and disseminated to farmers. The tuber yield of the varieties ranged from 272 qt/ha (Variety Qulle 272 qt/ha) to 644.8 qt/ha (Variety Chemere 644.8 qt/ha). All the released varieties have relatively homogeneous maturity groups which varied from 12 to 18 months (Table 1). Therefore, a continuous breeding and selection program is necessary to develop high-yielding, elite varieties and cultivars with different maturity classes for variable agroclimatic conditions. On the other hand, cassava seeds are genetically diverse due to the process of segregation and sexual reproduction. Unlike many other major crop plants, genetic improvements of cassava through sexual crosses have been difficult. Many cultivars flower infrequently and produce seed at a low rate. Furthermore, early flowering is associated with heavy branching, which tends to result in a low harvest index and yield (Cock, 1982) [18]. Nassar and Ortiz (2007) reported that cassava improvement via conventional methods continues to get genetic variation, which is needed to enhance the nutritional quality of this vital crop.

Table 1. List of Released Cassava Varieties in Ethiopia (2005-2021)

SN	Variety	Year of Release	Altitude	Days to Maturity	Yield (qt/ha)	Centre of Release
1	Kello (44/72 red)	2005	1200-1800	12-18 months	281	Hawassa
2	Qulle (104/72 Nigeria red	2005	1200-1800	12-18 months	272	Hawassa
3	Hawassa 4 (MM 96/7151	2016	1200-1800	16-18 months	420.8	Hawassa
4	Chichu (TMS 191/0427	2016	1200-1800	16-18 months	352.8	Hawassa
5	Melko-108 (AAGT-108)	2019	1000.1700	16-18 months	450.7	Jimma
6	Chemere (TA1050127)	2021	1000.1700	16-18 months	644.8	Jimma

B. Agronomic Research

In identifying suitable legumes for cassava-legume intercropping, intercrops of common bean, cowpea, soybean, and mung bean increased land use efficiency, suggesting that actual productivity was higher than expected when cassava was intercropped with these legumes. Thus, farmers producing cassava have the option to plant with grain legumes, thereby obtaining alternative crops that minimise risk and utilise the land more efficiently. A research study revealed that the impact of planting position and planting material on root yield of cassava. The study found that planting position and planting material had a profound influence on root yield, where slant and vertical plantings of the main stem top and middle parts are recommended for cassava production. The assessment results of plant density (inter and intra-row spacing) indicated that 100 cm row spacing and 80 cm plant spacing are optimum for cassava production. However, the plant density may vary depending on the type of varieties and environment. A study on the effects of harvesting stage and cultivars on starch quality and quantity showed that the highest pH and viscosity of tuber starch were observed when cassava was harvested 18 months after planting. Moisture content and pH were significantly reduced when harvesting goes beyond 15 months. On the other hand, neither the harvesting stage nor variety has any effect on the colour and dry appearance of the cassava starch. Both varieties (Qulle and Kelo) yielded relatively superior tubers when harvested 18 months after planting. Cassava/maze intercropping at various spatial arrangements revealed that the highest maize grain yield was achieved with one row of maize and one row of cassava (1M:1C) intercropping. In contrast, tuber yield of cassava was unaffected when intercropped with maize. Cassava can be planted at any time of the year, provided moisture is available in the soil through rainfall or irrigation. However, a planting date trial carried out showed that planting from March to May is better than other planting dates in the major cassava-growing areas of Ethiopia. At planting, there should be sufficient moisture to achieve 80-90% germination; however, if the soil is waterlogged, aeration and root formation are usually hindered. The harvesting date study for released varieties Qule and Kelo revealed that harvesting 18 months after sowing gave the most significant root yield. However, starch contents are higher if cassava is harvested in dry months. A study on land preparation

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methods indicated that furrow and ridge planting produced a superior root yield compared to flat planting. Flat, furrow and ridge planting were compared under different plant density scenarios at Amaro. Results showed that furrow and ridge planting produced comparable yields of 48 t/ha and 43 t/ha, respectively, compared to the 38 t/ha yield produced by flat planting. This might be due to the reappearance of a moisture conservation advantage, which subsequently manifested in the broader canopy diameter, increased root length, and diameter of cassava. However, manual harvesting required deeper digging, more labour and time in furrow planting compared to others. Therefore, planting cassava in ridges was recommended in the Amaro area.

Cassava-growing farmers have been using only two types of inorganic fertilisers, supplying N and P in the form of di-ammonium phosphate (DAP) (18% N, 46% P2O5) and urea (46% N). The amount of P in P2O5 varied from 0 to 32.2 kg/ha, with a mean value of 6.12 kg/ha, while the N application ranged from 0 to 19.2 kg/ha, with an average amount of 3.6 kg/ha. The results generally suggested limited use of fertiliser (organic and inorganic) for cassava production (Fanuel, 2016) [29]. Tewodros *et al.* (2021) showed that cassava tuber yield is influenced by nitrogen and phosphorus fertilisation. Hence, the growth and yield of cassava were significantly enhanced with the application of 40 kg N and 92 kg P2O5/ha, which is an economically optimal recommendation for cassava production in Jimma and its vicinity. Likewise, Zerihun and Yetinayet (2023) indicated that the interaction effects of N and K fertiliser rates did not significantly influence fresh tuber yield of cassava. However, they recommended 92 kg/ha N only, whereas K and its interaction with N require further investigation for cassava production in the Arba Minich area. Studies on crop improvement, agronomic practices, and fertility needs further investigation in variable agro-ecologies where the crop is potentially being produced.

C. Nutritional, Medicinal and Anti-nutritional Research

i. Nutritional Research

Nutritional composition of cassava tubers and leaves is presented in Table 1. It was observed that there were wide ranges of variation identified for most of the biochemical characters studied. Generally, biochemical analysis revealed that cassava tuber contains higher food energy, dry weight and total carbohydrate as compared to cassava leaf. Hence, cassava tubers are an energy-dense food that shows very efficient carbohydrate production per hectare. It produces approximately 250,000 calories per hectare, ranking it before maize, rice, sorghum, and wheat (Okigbo, 1980). On the other hand, cassava leaf is found to contain relatively higher moisture, protein, lipid, dietary fibre, and ash than that of the tuber. Nnaji *et al.* (2010) reported a relatively high crude protein content in cassava leaves, accounting for 26.3% of the dry matter in the foliage. Tubers contain a high carbohydrate content, averaging 30.70 g/kg fresh weight, of which 8% is produced as starch (Gil and Buitrago, 2006). The remaining 83% is in the form of amylopectin, and 17% is amylase (Rawel and Kroll, 2003). Cassava has been categorised into bitter and sweet types based on the amount of sucrose and dextrose content. In sweet cassava types, up to 17% of the tuber is sucrose with small amounts of dextrose and fructose (Okigbo 1980; Abo-Salem *et al.*, 2009) [2]. Dietary fibre is considered an essential part of a healthy diet and is expected to help reduce constipation problems. Research currently suggests that a mixed fibre diet may help prevent colon cancer. More dietary fibre is contained in leaves than tubers. However, its content depends on cultivar and its age. The lipid and ash content in cassava tubers and leaves varies, with higher content in the leaves. The lipids are either nonpolar (45%) or contain different types of glycolipids (52%).

Cassava tubers and leaves contain different types of vitamins in variable amounts (Table 2). Generally, the vitamin contents range from 0.05 mg/100 g riboflavin to 32.45 mg/100 g ascorbic acid in tuber and 0.19 mg/100 g thiamin to 100050 ug vitamin A in leaves. Cassava leaves are richer in vitamin content than tubers. Likewise, cassava tubers and leaves contain calcium, iron, potassium, magnesium, copper, zinc, and manganese, which are comparable to those found in many other legumes. Leaves contain a higher amount of Ca, P, K, Mg, Cu, and Zn, whereas tubers have a relatively higher amount of Fe, Na, and Mn. The essential amino acid content of cassava is presented in Table 3. Cassava tubers and leaves are rich sources of protein, and their crude protein content is comparable to that of fresh eggs. The amino acid profile of cassava leaf protein is well balanced compared to that of the egg except for methionine, lysine and may be isoleucine (Jacquot, 1957) [48]. Indeed, the main amino acids present in cassava proteins are arginine, histidine, isoleucine, leucine, and lysine. Sulphur amino acids are deficient, particularly lysine, methionine, tryptophan, cysteine and cystine. These are limiting amino acids in the root. Moreover, cassava leaves have an essential amino acid content higher than soybean protein and FAO's recommended reference protein intake (Okigbo, 1980).

Table 2. Nutritional Composition (Mean Values) of Cassava Tubers and Leaves Per Kilogram

Proximate Composition Per Kilogram	Tubers S	Leaves
Food energy (kcal)	124.5	91.00
Moisture (g)	65.60	76.70
Dry weight (g)	34.55	23.65
Protein (g)	1.90	5.50
Lipid (g)	0.27	1.55
Total carbohydrate (g)	30.70	12.65
Dietary fiber	1.90	5.25
Ash	1.05	2.60
Vitamins (mg/100 g) composition	Roots	Leaves
Thiamin (mg)	0.16	0.19
Riboflavin (mg)	0.05	0.48
Niacin (mg0	0.85	2.05
Ascorbic acid (mg)	32.45	215.00
Vitamin A (ug)	20.00	10050.00
Mineral composition	Roots	Leaves
Calcium (mg)	97.50	371.00
Phosphorus (mg)	79.00	119.00
Iron (%)	7.15	4.35
Potassium (%)	0.49	0.79
Magnesium (ppm)	0.06	0.27
Copper (ppm)	4.00	7.50
Zinc (ppm)	27.50	160.00
Sodium (ppm)	144.50	114.00
Manganese (ppm)	6.50	112.00

Table 3: Amino Acid Profile of Cassava

Amino Acid	Content in Roots			Content in Leaves		
	Wet Weight (%)	Dry Weight (%)	Protein (%)	Wet Weight (%)	Dry Weight (%)	Protein (%)
Arginine	0.10	0.29	11.00	0.30	1.48	5.30
Histidine	0.02	0.07	2.60	0.13	0.66	2.30
Isoleucine	0.01	0.03	1.00	0.33	1.67	5.90
Leucine	0.11	0.31	11.70	0.54	2.72	9.70
Lysine	0.02	0.07	2.60	0.37	1.87	6.70
Methionine	0.01	0.03	1.00	0.07	0.36	1.30
Phenylalanine	0.01	0.03	1.00	0.18	0.92	3.30
Threonine	0.01	0.03	1.00	0.27	1.35	4.80
Tryptophan	-	0.29	0.50	0.05	0.24	0.80
Valine	0.01	0.04	1.50	0.20	0.99	3.50
Alanine	0.05	0.15	5.70	0.34	1.70	6.10
Aspartic acid	0.04	0.13	4.90	0.49	2.44	8.70
Cysteine	0.003	0.01	0.40	0.04	0.21	0.70
Glutamic acid	0.05	0.15	5.70	0.40	1.99	7.10
Glycine	0.003	0.01	0.40	0.35	1.73	6.20
Proline	0.01	0.03	1.00	0.18	0.88	3.10
Serine	0.01	0.04	1.50	0.34	1.68	6.00
Tyrosine	0.003	0.01	0.40	0.18	0.89	3.20

ii. Edicinal Research

Various phytochemicals present in cassava have numerous medicinal uses, which have been highlighted in this review. Numerous studies have demonstrated that the presence of multiple phytochemicals in cassava makes it a potential remedy for various ailments, including diabetes, celiac disease, bone and neurological health issues, cardiovascular diseases, prostate problems, allergies, gastrointestinal disorders, and high blood pressure.

D. Effects on Cardiovascular Diseases

One of the most valuable mineral contributions of tapioca (cassava starch) is its iron content, which is essential for the normal functioning of the human body, particularly in the creation of new red blood cells. Hence, the iron in tapioca, together with copper, increases the number of red blood cells in the body, thereby preventing anaemia and related conditions. With more red blood cells, extremities are guaranteed a healthy flow of blood and oxygen, which keeps those cells healthy and operating at their optimal levels. Thus, cellular re-growth and maintenance are improved, which accelerates wound healing (Wobeto *et al*., 2006).

VII. EFFECT ON GASTROINTESTINAL TRACT PROBLEMS

The fibre content in tapioca has been directly linked to improving several conditions within the human body, with the most notable being digestion. Fibre bulks up stool, which helps to move it through the digestive tract, thereby eliminating constipation, bloating, intestinal pain and even more serious conditions like colorectal cancer. Moreover, fibre helps to boost heart health by scraping excess cholesterol off the walls of arteries and blood vessels, thereby helping to eliminate atherosclerosis and associated issues, such as heart attacks and strokes (Jayasri *et al.,* 2011) [46].

A. Effect on Blood Pressure

Tapioca from cassava contains potassium, another essential mineral, which also acts as a vasodilator that reduces tension and stress in blood vessels and arteries. This can increase blood flow to parts of the body and reduce strain on the cardiovascular system. This reduction in atherosclerosis results in a much smaller chance of blood clots getting stuck and causing fatal events like heart attacks or strokes. Furthermore, potassium is crucial for maintaining fluid balance in the body. When it is in proper balance with sodium, fluid exchanges can occur smoothly, further enhancing metabolic efficiency and energy (Trinidad *et al*., 2013).

B. Effect on Celiac Disease

The absence of the allergenic protein gluten makes cassava flour a suitable substitute for rye, oats, barley, and wheat. Individuals diagnosed with celiac disease and other gluten-related allergies can find relief in consuming foods made with tapioca or cassava flour. Although baking cakes, bread and other foods requires gluten to enable them to swell in size, it can be substituted with guar and xanthan gum (Dorota *et al*., 2014) [25].

C. Bone and Neurological Health

Tapioca is a rich source of vitamin K, calcium and iron, all of which play essential roles in the protection and development of bones. Bone mineral density decreases with age, leading to conditions such as osteoporosis, osteoarthritis, and general weakness and reduced flexibility. If tapioca is regularly consumed, our bones can be protected, developed, and maintained as we age. The wealth of vitamin K does more than promote osteotrophic activity; it is also essential for our mental health. It has been shown that vitamin K can reduce the chances of developing alzheimer's disease by stimulating neuronal activity in the brain. Alzheimer's disease often occurs due to a lack of activity or mental stagnation; vitamin K helps keep neural pathways active and engaged, and free of free radicals that can cause a breakdown of brain tissue (Charles *et al*., 2004) [16].

D. Effect on Prostate Problems and Allergies

Long-term observations on the medicinal effect of *Manihot esculenta* are related to prostate problems and allergies. Several decades of observations in Western European countries, along with a few clinical tests, have demonstrated cassava's effectiveness in treating prostate problems, ranging from infections and swelling to cancer (Anbuselvi and Balamurugan, 2014) [5]. It appears that consumption of cassava in large quantities in the diet has no biochemically evident therapeutic benefit in castration-resistant prostate cancer. A single case may not be adequate to test a hypothesis. However, in the absence of scientific publications about the effects of cassava on prostate cancer, this scientifically tested case would act as a basis of evidence that can be used by health care workers who look after patients with castration-resistant prostate cancer as well as by patients with the disease until further research is done. Better evidence is available (Abeygunasekera and Palliyaguruge, 2013) [1].

i. Anti-nutritional Research

Anti-nutrients are referred to as nutritional stress factors which may either be in the form of synthetic or natural compounds that impede nutrient absorption. Cassava contains anti-nutritional and toxic substances that impair nutrient uptake and absorption. The commonly occurring anti-nutrients include cyanide, phytates, nitrates and nitrites, tannins/phenolics, and oxalates (Table 4).

ii. Cyanide

Cyanide, which occurs as cyanogenic glucosides, is a toxic compound that has been associated with adverse health effects on human beings. High cyanide intake from the consumption of insufficiently processed cassava can cause acute toxicity such as vomiting, stomach pains, giddiness and headache. Moreover, the adverse effects noted in humans from long-term cassava consumption include diseases such as "Konzo" or upper motor neuron diseases, iodine deficiency disorder (goitre), and tropical ataxic neuropathy (Tylleskar *et al*., 1992; Okafor, 2004). The level of cyanide in cassava is defined by the type of cassava used as a reference, with each variety exhibiting different levels of this toxic compound. Excessive intake of cyanide is known to cause cretinism and goitre, which are associated with iodine deficiency (Nhassico *et al*., 2008). This is as a result of the production of thiocyanate as a by-product of cyanide metabolism, which restricts the uptake of iodide by thyroid gland (Ermans *et al*., 1980) [26]. As such, before consumption, it is essential to process cassava leaves properly to reduce their cyanide content (Gomez and Valdivieso, 1985) [39]. Likewise, cyanohydrins from aldehydes may also persist even after cooking, as they are thermally stable (Onabolu *et al*., 2002). Therefore, boiling is often criticised as an ineffective standalone method of detoxifying cassava roots; hence, it is preferred as a method of processing sweet cassava, although heat favours the rapid evaporation of hydrogen cyanide (HCN) produced (Bokanga, 1995) [13]. The level of cyanide in cassava exceeds 10 mg/kg dry weight, which is the recommended maximum consumption level set by the World Health Organisation and the Food and Agriculture Organisation. This makes cassava leaves highly toxic for human consumption. The content of cyanide in cassava tubers is significantly lower (approximately 10 times lower) compared to the leaves, which is an aspect that explains its utilisation for methodological standardisation (Haque and Bradbury, 2003) [43].

Hydrocyanic acid inhibits the enzyme cytochrome oxidase (preventing oxidative production of energy) and interferes with oxygen binding to haemoglobin (Siritunga and Sayre, 2004). Hydrogen cyanide inactivates the enzyme cytochrome oxidase in the mitochondria of cells by binding to the Fe^{3+}/Fe^{2} contained in the enzyme. This results in a decrease in oxygen utilisation in the tissues. Cyanide causes an increase in blood glucose and lactic acid levels, as well as a reduction of the ATP/ADP ratio, indicating a shift from aerobic to anaerobic metabolism. Cyanide activates glycogenolysis and shunts glucose to the pentose phosphate pathway, decreasing the rate of glycolysis and inhibiting the tricarboxylic acid cycle. Hydrogen cyanide will reduce the energy availability in all cells, but its effect will be most immediate on the respiratory system and heart. Based on cyanide content, cassava varieties are classified into three categories: sweet varieties with cyanide levels less than 50 mg/kg, those with 100 mg/kg fresh weight, and intermediates that contain between 50 and 100 mg cyanide/kg (Kobawila *et al*., 2005) [55]. Linamarin is chemically similar to glucose, but with a cyanide (CN-) ion attached.

iii. Phytate

Phytate is an anti-nutrient that regulates intracellular signalling and forms the phosphate storage component in plant seeds, binding proteins and minerals in the gastrointestinal tract and making them unavailable for absorption and utilisation by the body. In particular, phytate has a binding effect on multivalent metal ions, including zinc, iron and calcium, all of which are essential nutrients. This leads to formation of highly insoluble salts and minerals that are less bioavailable (Rhou and Erdman, 1995).

iv. Nitrates and Nitrites

Nitrates occur naturally in most soils and water sources; therefore, they are taken up by growing plants. Leafy vegetables are the primary contributors of nitrates in diets, accounting for approximately 75% of the total food ingested. Nitrates themselves are not toxic at the levels present in most foods, but toxicity occurs when nitrates are reduced to nitrites (Mohri, 1993). When high levels of nitrates in vegetables are ingested, they are changed to nitrite. This can result in the development of blue-baby disease, methemoglobinemia, or cancer (Gupta *et al*., 2002) [41]. However, since nitrates and nitrites are water soluble, some amounts may be lost through leaching during the preparation process. Furthermore, most of the nitrites present are oxidised to nitrate, and upon cooking, they leach out of the vegetable (Ricardo, 1993).

v. Tannins/Phenolics

They are referred to as polyphenolics, which are anti-nutritional agents. Data on polyphenols found in cassava leaves is expressed by researchers as tannin equivalents while employing a non-specific method.
assay (Fasuyi, 2005 [30]; Wobeto *et al*., 2007). Polyphenols, as

antioxidants, bind to various minerals in food, reducing their bioavailability. Moreover, they impair the functionality of digestive enzymes by slowing down digestion and, in some cases, cause protein precipitation (Beecher, 2003) [12]. The levels of tannins in plants vary and may be influenced by factors such as germination, storage, and processing time. Increasing phenolic compound levels are known to decrease fertility among women of reproductive age by altering hormone levels, thereby affecting early stages of pregnancy (Greenwell, 2000) [40].

vi. Oxalates.

Oxalates are dicarboxylic acids that are present in plant-based foods, such as cassava, which hurt the bioavailability of magnesium and calcium. These anti-nutritional agents bind to calcium, leading to the formation of crystals or their excretion through urine. The crystals that form (calcium oxalate) majorly contribute to kidney stones. It is highly advisable to reduce oxalate intake and promote calcium intake among individuals at risk of kidney stones (Massey, 2007) [57]. Less attention had been given to the importance of oxalate levels in foods until recently, as it was believed that only 10% of the calcium excreted daily was due to dietary calcium (Massey, 2007). The impact that oxalates have on human health is highly dependent on calcium availability and the amount of oxalate consumed. According to Wobeto *et al.* (2000), cassava's calcium-to-oxalate ratio is as high as 5, which surpasses the recommended 0.44%, below which calcium uptake is endangered. As such, the level of oxalates in cassava leaves has no negative impact on calcium uptake. Nevertheless, groups that consume cassava leaves should consider breeding different varieties of cassava to obtain types that have lower levels of oxalates and enhanced calcium. Cassava leaves have an oxalate concentration of between 1.35 and 2.88 g/100 g of total dry weight (Wobeto *et al.,* 2007), which warrants attention in breeding and processing.

Table 4: Anti-Nutrient Levels (mg/100 g) of Cassava in Wet Weight

Anti-nutrient	Level (mg/100 g)	Remark
Phylates	191.25	-
Oxalates	15.74	-
Tanins	0.65	-
Cyanide	25.69	-
Nitrates	3.58	-

VIII. HARVESTING, PROCESSING AND UTILIZATION

E. Harvesting

Cassava is usually harvested after one year of planting. However, because of its perennial nature, it continues to grow for several years if left in the ground. Traditionally, it is harvested by cutting off the top growth about 20 cm from the ground and then pulling on the remaining stump of the stem until the roots emerge from the ground. The upper parts of the stems with the leaves are removed before harvest (Nassar and Ortiz, 2007). High yield of foliage in cassava was obtained by managing the crop as a semi-perennial with repeated harvesting of the foliage at 2–3 month intervals (Foulkes and Preston, 1978) [35].

F. Processing

Cassava tubers, once harvested, deteriorate rapidly within 40 to 48 hours, primarily due to physiological changes and/or mechanical damage that occur during harvesting, transportation, and handling. Cyanide is the most toxic substance, restricting consumption of cassava roots and leaves. Consumption of 50 to 100 mg of cyanide is acute, poisonous and lethal to adults (Siritunga and Sayre 2003). On the other hand, lower consumption of cyanide is not deadly, but long-term intake can cause severe health problems like tropical neuropathy. People ingesting cyanide and high amounts of nitrates and nitrites have the risk of developing stomach cancer. Individuals who consume cassava have a high level of thiocyanate in their stomachs due to the body's cyanide detoxification process, which may catalyse the formation of carcinogenic nitrosamines (Wobeto *et al*., 2007). Moreover, oxalates are anti-nutrients affecting Ca and Mg bioavailability and form complexes with proteins, which inhibit peptic digestion. Hence, proper processing of cassava before consumption is of paramount importance. Various processing methods help reduce the cyanide content and avoid toxicity in the crop. These methods include peeling the cover, sun drying, fermenting, and heat cooking. Among these, fermentation and heat cooking can reduce cyanide to a nontoxic level (IITA, 2007) [45]. Cassava processing techniques that reduce its toxicity, improve palatability, increase shelf life, facilitate transportation, and convert the perishable fresh tuber into stable products encompass these.

G. Breeding

Selection of cultivars of cassava with inherently low levels of anti-nutritional factors would have a considerable impact on the efficiency of cassava production. A plant breeding strategy of reducing the level of antinutrients in the grain has often been suggested as a means to achieve this objective. Such attempts to significantly lower the anti-nutrient content of seeds and grains require a significant shift in seed or grain composition. Because most of the anti-nutrients known to occur in seeds and grains are major organic constituents of these organs, they may play additional beneficial roles in plant growth and human health. However, breeding requires long-term efforts compared to other methods, as the type of plant and the number of unwanted components are both large and diverse, concerning the chemical and biochemical nature of the compounds. Breeding for low cyanide level cassava [22] genotypes involves genetic improvement through the removal of genes responsible for the formation of linamarin (cyanogenic glucoside), which is responsible for the toxicity of cassava.

H. Biotechnology techniques

Complete detoxification of "bitter" cassava varieties can feasibly be accomplished through the enzyme-catalyzed degradation of both cyanogenic glucosides and the cyanohydrins which result from their degradation.

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I. Peeling

Peeling is the removal of the outer skin of cassava. It is an essential process in cassava because cassava peels contain higher cyanide content than the pulp. Removal of the peels therefore reduces the cyanogenic glucoside content considerably. Cassava genotypes can be of two types, with sweet varieties having the most cyanide in the cortex and skin and little to no cyanide in the pulp. In contrast, the bitter varieties have an even distribution of cyanide throughout the tuber, although this is not entirely consistent. Peeling, therefore, can be an effective way to reduce the cyanide content by at least 50% in cassava tubers (Zemach, 2013). However, it should be noted that while the peel contains high glucoside content relative to the pulp, the glucosidase level is higher in the latter.

J. Grating

Grating is carried out after peeling and may sometimes be applied to whole tubers. Grating of the whole tuber ensures the even distribution of the cyanide in the product and makes the nutrients contained in the peel available for use. In the grated product, the concentration of cyanide depends on the time during which the glucoside and the glucosidase interact in an aqueous medium. Moreover, grating provides a larger surface area for fermentation to occur.

K. Soaking

Soaking is the process of steeping cassava in water, which facilitates the greater extraction of soluble cyanide. The process removes about 20% of the cyanide in fresh root chips after four hours. However, in soaking, the bound cyanide is only negligibly reduced. Bound cyanide begins to decrease only after the onset of fermentation (Cooke and Maduagwa, 1978) [19]. A significant reduction in total cyanide is achieved if the soaking water is changed routinely over three to four days. The fermentation of soaked tubers in water is more effective than that of grated tubers in reducing cyanogens. Indeed, more than 90% of the total cyanogens are removed after three days of fermentation, and about one-third of the initial linamarin is found in the water (Westby and Choo, 1994).

L. Boiling

Boiling as a processing technique for cassava roots is employed in nearly all countries where cassava is utilised as a food source. Boiling destroys the enzyme linamarase at about 72°C, thus leaving a considerable portion of the glucoside intact. Therefore, it is crucial to consider the optimal temperature when processing cassava through boiling. However, the technique is inefficient for cyanide removal. The inefficiency of this processing method is due to the high temperature, where at 100 °C, linamarase, a heat-labile enzyme, is denatured, and linamarin cannot then be hydrolysed into cyanohydrins. According to Cooke and Maduagwa (1978), bound glucosides are reduced to 45-50% after 25 minutes of boiling. Free cyanide and cyanohydrine in boiled cassava tubers are found at very low concentrations. Cyanohydrins and free cyanides are volatilized during boiling, which reduces the content in boiled cassava tuber (Oke, 1994).

M. Drying

Drying is the simplest method of processing aimed at reducing the moisture, volume, and cyanide content of the tuber, thereby prolonging the product's shelf life. This process is practised primarily in areas with a limited water supply. The total cyanide content of cassava chips can be decreased by only 10-30% through fast air drying. Sun-drying the peeled cut pieces of tuber resulted in a HCN concentration lower than 10 mg/100, and the loss was more effective than oven drying (Mahungu *et al*., 1987) [56]. Generally, drying is not an efficient means of detoxification, especially for cassava varieties with high initial cyanogenic glucoside content. However, sun-dried products are the most common type of cassava processed products in Africa (Westby, 2000).

N. Detoxification

Enzymatic removal of cyanogens is commonly accomplished by treating samples with enzymes isolated from bacteria to break down cyanogenic compounds into acetone cyanohydrins, which decompose spontaneously to HCN or by treating with plant cell wall-degrading enzymes such as cellulolytic and pectolytic enzymes to enhance the release of linamarin and allow for more contact time with linamarinase (Yeoh and Sun, 2001). Detoxification essentially involves strengthening the interaction between linamarase and its substrates (Cyanohydrins), followed by the volatilisation of HCN produced as a result of this interaction. The enzyme hydrolysis of cyanogens is sensitive to changes in pH, with a pH greater than 5 favouring the breakdown of the process (Cumbana *et al*., 2007) [20]. Species of bacteria, including Bacillus, Pseudomonas, and Klebsiella oxytoca, have been reported to utilise cyanide as the sole source of nitrogen under both aerobic and anaerobic conditions, thereby breaking it down into non-toxic compounds (Kaewkannetra et al., 2009) [51]. A shortcoming of detoxification methods is that they result in significant nutrient loss (Murugan *et al*., 2012).

O. Fermentation

Fermentation is a method of processing that primarily enhances nutritional properties through the biosynthesis of vitamins, essential amino acids, and proteins, by improving protein quality and fibre digestibility, as well as enhancing micronutrient bioavailability and degrading anti-nutritional factors (AOAC, 1990; Motarjemi, 2002) [10]. Some lactic acid bacteria and yeast possess linamarase activity and are recognised for significantly contributing to the breakdown of cyanogenic glycosides during the fermentation of cassava (Kimaryo *et al*., 2000) [54]. These microorganisms are capable of utilising cyanogens and their degradation products, thereby ridding their substrate of these noxious substances and rendering the substrate safe (Akindahunsi *et al*., 1999) [3]. Three major types of fermentation are widely practised in different parts of the world.

Africa: grated root fermentation, mould fermentation of roots in heaps, and fermentation of roots under water (Westby, 2002). Fermentation of cassava roots is primarily acidic (pH 3.8), while that

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of leaves is alkaline (pH 8.5), with lactic acid bacteria dominating the microbiota (Oyewole and Ogundele, 2001). Findings indicated that a remarkable reduction in cyanogenic potential of cassava following fermentation with more than 50 %, 35 % and 41% reduction in cyanogen levels was achieved in the production of gari, fermented cassava flour and during fermentation, respectively (Kemdirim *et al*., 1995 [52]; Djoulde *et al*., 2007 [24]; Enidiok *et al*. [27], 2008). Indeed, reduction in cyanide level in all cases depends on the initial cyanide levels of the raw material.

P. Utilization

The utilisation of cassava root as a food source and as an industrial raw material is limited due to the rapid postharvest deterioration that begins within two days after harvest. This situation shortens the shelf life of the root, leading to postharvest loss and poor market quality of fresh root and minimally processed cassava food products, such as gari and flour (Van Oirschot *et al*., 2000). Moreover, a toxic compound associated with cassava root also contributes to the limited utilisation of this crop as a food.

IX. CASSAVA DISEASES AND PESTS

A. Diseases of Cassava

Cultivation of cassava is hampered by several diseases which limit cassava production in Ethiopia. Commonly known diseases of cassava include cassava mosaic disease, bacterial blight, anthracnose disease, cassava bud necrosis and root rots. Some of these diseases affect the leaves and stems of cassava plants, while others target the plant's storage roots. Some of the major diseases are briefly described as follows.

B. Cassava Mosaic Disease

It is caused by a cassava mosaic virus which occurs inside cassava leaves and stems. The symptoms include discolouration of patches with a standard green colour, mixed with light green, yellow, and white areas. This discolouration is known as chlorosis. The chlorotic patches can be confused with damage caused by cassava green mite feeding. When cassava mosaic attack is severe, the leaves are tiny and distorted, and the plants are stunted. The disease symptoms are more pronounced in younger plants, usually those under six months old, than in older plants. The primary sources of the virus which causes cassava mosaic disease are cassava plants with the disease and the whitefly (*Bemisia tabaci)*. The virus is transmitted through the saliva of the whitefly, and the insect injects saliva containing the virus into the cassava leaves during feeding. The virus multiplies and occurs in large numbers in the leaves and stems. Cassava mosaic disease is also spread by planting stem cuttings from infected plants.

C. Cassava Bacterial Blight

Cassava bacterial blight is caused by a bacterium which occurs inside cassava leaves and stems.

Damage symptoms of cassava bacterial blight appear as water-soaked, dead spots (lesions) on the leaves. The lesions occur between leaf veins and are most evident on the lower surfaces of the leaves. These angular lesions later merge into larger patches, eventually killing the leaf blade as they enlarge. The leaf blade turns brown, with a water-soaked area at the leading edge of the brown patch, which is known as leaf blighting. Severely blighted leaves wilt, die and fall, causing defoliation and shoot tip die-back or complete death of the shoot. The symptoms of cassava bacterial blight are more evident in the wet season than in the dry season. The disease is more severe in young plants than in older ones. The primary source of the bacterium that causes cassava bacterial blight is cassava plants with the disease. The bacterium enters cassava plants through wounds and scratches on the stems and leaves.

D. Cassava Anthracnose Disease

Cassava anthracnose disease is caused by a fungus which occurs on the surface of cassava stems and leaves. It appears as cankers (sores) on the stems and bases of leaf petioles. Cankers weaken the petioles so that the leaf droops downwards and wilts. The wilted leaves die and fall, causing defoliation and shoot tip dieback or complete shoot death. Soft parts of cassava stems become twisted under severe attack by the disease. The disease typically begins at the start of the rainy season and worsens as the wet season progresses. The primary sources of the fungus that causes the disease are cassava plants with the disease, which spread by wind carrying spores from cankers on the stems, or by planting stem cuttings with cankers. The fungus enters cassava plants through wounds and feeding punctures made by the bug (*Pseudotheraptus devastans*). Dead cassava stems and leaves with the fungus also serve as sources of the disease if they are not destroyed after root harvest.

E. Cassava Bud Necrosis

Cassava bud necrosis is caused by a fungus which occurs on the surface of cassava stems and leaves. The disease appears as patches of brown or grey fungal matter covering the stem. The fungal matter sometimes covers buds (eyes) on cassava stem cuttings. The affected buds die, which reduces the ability of stem cuttings to sprout. The primary sources of the fungus that causes bud necrosis are cassava plants with the disease. Dead cassava stems and leaves with the fungus also serve as sources of the disease if they are not destroyed after root harvest. The fungus primarily spreads by wind; however, the planting of infected stem cuttings is the primary method by which the disease is transmitted. The fungus that causes bud necrosis also causes leaf spots on a variety of plants, including grasses, cereal crops, bananas, and mangoes.

F. Leaf Spot Diseases

Fungi cause cassava leaf spot diseases and are of three different types: white leaf spot, brown leaf spot, and leaf blight. Cassava white leaf spot disease appears as circular white or brownish-yellow spots on the upper leaf surfaces, and the spots sometimes have purplish borders around them. Likewise, cassava brown leaf spot disease appears as small brown spots with dark borders on the upper leaf surfaces.

The brown spots occur between leaf veins, and their sizes and shapes are limited by the distance between these veins. The dead tissue in the centre of brown spots may fall to give the leaf surface a “shot hole” appearance. Under severe attack, the infected leaves become yellow, dry and die prematurely. Cassava leaf blight disease appears as light brown lesions on the upper surfaces of the leaves, and veins do not limit the lesions and are usually larger than brown leaf spots. The lesions may enlarge to cover most of the leaf surface, causing leaf blighting. The blighted leaves lack water-soaked areas, which are typical of leaf damage caused by cassava bacterial blight. The primary sources of fungi that cause leaf spot diseases are infected cassava leaves [47] on the plant or those that have fallen to the ground. The fungi spread to new plants from these sources by wind or rain splashes. Leaf spot fungi can occur on weeds, which then serve as sources for the disease to spread.

Generally, the most practical control methods of cassava diseases are (1) plant disease-resistant cultivars; (2) use adequate cultural practices; and (3) plant disease-free material treated with fungicide. Currently, cassava improvement programs focus on long-term research to develop and release high-yielding, multiple-disease-resistant cultivars. This will take some time; however, the foregoing recommendations should provide effective short-term control, which should minimize the incidence and spread of cassava diseases. Moreover, there are very few economically feasible chemical control measures for cassava diseases.

G. Insect Pests

The most important insect pests attacking cassava are the cassava scale insect (Aonidoytilus albus), the cassava green mite (Mononychellus tanajoa), and the red spider mite (Tetranychus spp.). Among the three cassava insect pests, the most severe one is the cassava scale insect, which frequently occurs in almost all cassava-producing areas in Ethiopia. Cassava scale *(Aonidomytilus albus)* (Cockerel) (Hemiptera: Diaspididae) was first reported in 2001 at Amaro, affecting cassava production and productivity in southern Ethiopia, particularly in the Amaro district (Mesele *et al*., 2007) [58].

X. CONCLUSION

Cassava plays a crucial role in Ethiopia, serving as a source of consumption, animal feed, and income for many rural and urban households. Despite its importance at the household level, cassava production and productivity are low compared to other crops. It is mainly cultivated by small, resource-poor farmers on small-holding plots of land and used as a food security crop; however, cassava can also be used as a source of industrial raw materials to produce starch, ethanol, bioplastics, high-quality flour, glue, and confectionery products, among others. Future research on cassava should focus on developing eco-friendly, site-specific, and sustainable varieties for production, taking into account the maturity period of the prevailing climatic conditions in a particular locality. Soil fertility management of essential nutrients is of paramount importance to maximise the productivity of cassava across the major soil types in Ethiopia. Hence, comprehensive integrated soil fertility management (ISFM) studies for early-, medium-, and late-maturing varieties, preferred by producers for the dominant soils found in major agro-ecologies, are recommended. Drought management is a crucial factor in increasing cassava productivity, and hence, cassava yields could be severely affected by water availability. Designing and assessing intercropping options, as well as crop rotation studies, are key areas that require research. There are different anti-nutritional factors (cyanide, phytate, tannin, and oxalates) in cassava that have not yet reached a safe level of recommendation for human consumption. Therefore, anti-nutritional factors removal techniques and further methods should be investigated and introduced to process leaves and roots from Ethiopian cassava varieties to reach a safe level. Since existing processing technologies are inefficient and require improvement, research should focus on developing new technologies for processing that enable producers to obtain high-quality products, making them more attractive and competitive in the market. Moreover, the most important diseases and insect pests are areas that require attention in future research for the development of relevant control methods.

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After aggregating input from all authors, I must verify the accuracy of the following information as the article's author.

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