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Review Paper

Biotechnological Improvement of Cassava Yield and Processing for Food Sustainability in Nigeria

*Angela Chika Udebuani [1], Chidinma Ogochukwu Ukachukwu [1]**

1) *Department of Biotechnology, School of Biological Sciences, Federal University of Technology Owerri, Imo State, Nigeria.*

*) *Corresponding Author: c.chaichana@eng.cmu.ac.th*

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***Abstract*— Cassava (*Manihot esculenta*) was introduced into Nigeria by Portuguese merchants in 1501. Since then, it has become a major source of food and raw materials leading to an increase in demand. In Nigeria, two-thirds of the States, mainly in the southern region, produce cassava. Malnutrition among the rural populace, especially children and women has led scientists to device means of increasing the nutritional content and varieties of cassava for food sustainability in Nigeria. Many genetically modified cassava species are produced and marketed in Nigeria. Today we have varieties with vitamin A, reduced carbohydrate content, disease resistance to mention but a few.**

Keywords—Genetically Modified Cassava, Nigeria, Food Sustainability, Raw Materials

I. Introduction

Cassava (*Manihot esculenta*) is considered as an important food security and income generating crop cultivated majorly by small scale farmers worldwide, especially in developing part of the world. Cultivation of cassava in Nigeria began during the period of the slave trade brought about by Portuguese merchants. Ever since then the crop has been produced in twenty-six of the country 37 states, this includes; Kaduna, Taraba, Benue, Cross river, Akwa Ibom, Ondo, Rivers, Imo, Oyo, Anambra, Enugu, Kogi, Kwara, Nassarawa, Ebonyi, Ekiti, Delta, Lagos, Edo, Abia, Osun, Niger, Kebbi, Plateau, Bayelsa and Ogun States [2]. It is majorly cultivated in the southern part of the country, where it grows very well under favorable weather and soil conditions which at times fluctuates, although cassava has the ability to adapt and survive even in harsh environmental conditions. Cassava is a staple food in Nigeria which provides high carbohydrate and energy content, and has been transformed to serve several purposes such as; domestic, agro-industrial and industrial uses [44]. The industrial sector has accessed cassava cellulose and starch, with the former is an important polymer in textile and paper industries while the later used in food industries. Furthermore, cassava has been transformed through the use of biotechnology processes to solve problems association with cassava production and enhancement. This have been achieved by improving agronomic traits as a result of transgenic technology such as virus resistance, reduced cyanide content, improved biomass and nutrient contents etc. Transgenic technologies has help in biofortification of cassava by improving certain traits for alleviating the risk associated with nutrient deficiency of cassava products such as night blindness (lack of vitamin A), low immune system (lack of iron and zinc) and kwashiorkor (protein deficiency) [53]. The purpose of transforming cassava using biotechnology techniques is to improve the performance of the plants in the field and also the development of new products with desired character for sustainability over a long term.

II. History of Cassava in Nigeria

The historical perspective of cassava in Nigeria is dated back to 1501 [2], when the early slave trader, the Portuguese merchants brought this edible starchy tuberous root from the west-central Brazil where it was first domesticated, about 10,000 years ago [33]. Researchers have considered the Portuguese merchants as people, who played major role in introducing cassava into Africa and in southern Nigeria in particular. However, its revolution began in the 1990s, when some of the slave traders returned back and brought the different techniques of processing and use of cassava as food and raw materials in the industries. Since then, cassava has become a household name and been used to fight food insecurity in the country. Twenty- six (26) out of the 37 states in Nigeria have adopted this crop plant as major economic sustenance crop and planting occurs during four planting seasons in the different geo-ecological zones that cultivates cassava. Such states include, Kaduna,Taraba, Benue, cross river, Rivers, Imo, Anambra, Ondo Enugu, Kogi, Akwa Ibom, and Ogun States which are seen as very high producers of cassava. Six states are classified as high producers of cassava and they include; Oyo, Kwara, Nassarawa, Ebonyi, Ekiti and Delta States. Five (5) states are classified as moderate producers of cassava and they include; Lagos, Edo, Abia, Osun and Niger States. While the lowest producers of cassava come from three (3) states and they are Kebbi, Plateau and Bayelsa states (Figure 1). In the southeastern states of Nigeria where cassava is cultivated, it grows very well in favorable temperature conditions of between 25 – 29 °C and rainfall of 2500 mm which at times fluctuates, though cassava has the vast ability to adapt and survive even in such conditions. Trees grow in canopies and leaves are shaded off, which decay and supply organic matter and other nutrients to the soil and its part of the reason for its good performance. In these regions, different types of soil ranging from sandy, loamy to clay soil have been identified, however sandy-loamy type with medium soil fertility and with good drainage gives the highest yield of cassava. These regions are also swampy especially in the Niger Delta areas where soils are under stagnant water, such areas are unsuitable for cultivation of cassava.

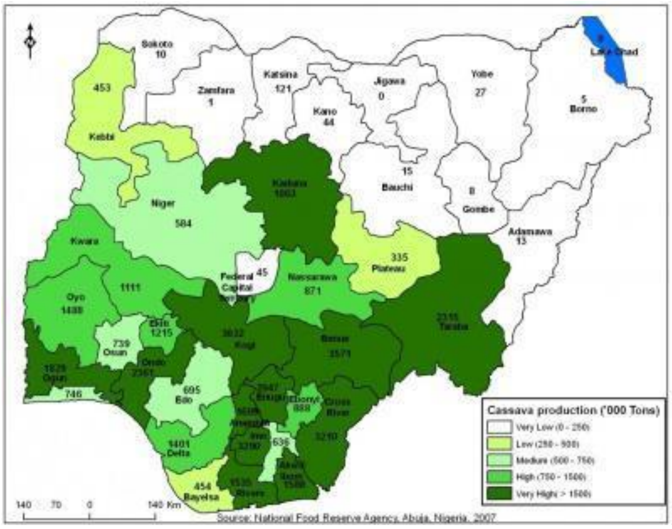

Fig 1: Map of Nigeria showing classification of cassava production from different states. Source; National Food Reserve Agency Abuja Nigeria (2007).

III. USES OF CASSAVA

Cassava is considered a staple food in Nigeria and known for its high carbohydrate and energy content. Over the years, cassava has been used for the production of food and raw materials for domestic, agro-industrial and industrial uses [44]. There are various uses of cassava which include the following:

A. Food

Cassava has represented a valuable food resources in many parts of Africa including Nigeria. Although cassava used as food is prepared in different ways, types or delicacies. Interestingly, when harvested, the peels of the tubers are used for livestock feed and the starchy part are consumed intentionally by the populace as flex (garri) or processed into flour which is made into fufu (a solid food that is swallowed with soup). Interestingly cassava processed food are valued food in Nigeria and many parts of African and Brazilian cultures. Cassava continues to make up 60 – 75% of dietary carbohydrate in southern part of Nigeria.

Production of Cassava as Flex (called Garri)

It is a major food product obtained from cassava processing and mostly common in the eastern part of the nation. It has two color variety of white and yellow (Plate 1). The yellow colored cassava flex is as a result of addition of red oil which is mixed with the flex during its preparation. Cassava flex preparation is virtually a common small-scale industrial activity practiced in all the residential homes even in rural areas in Nigeria. In preparing this flex, the root tubers are harvested and skin peeled, washed and grinded. The cassava paste is placed in a mash bag, tightened with rope and placed in a hydraulic press for atleast 2-4 days to allow detoxification through fermentation and draining of water in it. The drained cassava mash is fried dry to reduce the effect of cyanide [13]. Industrial processing of Cassava flex has about 8-10% moisture content when compared to the traditionally process flex (12 - 24%) [34]. It is a convenient food eaten as snacks by soaking in cold water mixed with sugar, milk, coconut and groundnut or eaten as main dish by preparing in hot water and use as swallow with soup [34]. Cassava flex is commonly sold by the dealers in the local and international markets; however, cassava flex has been prepared, packed and exported to some developed countries in recent times. Some microorganisms have been identified to help in the fermentation process of cassava flex. Such organisms include *Lysinibacillus spp, Proteus spp, Pediococcus spp, Lactobacillus plantarum, Staphylococcus spp, and Bacillus spp were confirmed to be Lysinibacillus alkalisoli , Proteus mirabilis, Pediococcus acidilactici, Lactobacillus plantarum, Staphylococcus aureus, Bacillus subtilis and Bacillus cereus while the fungi isolate Penicillium spp, Diutina spp, Rhizopus stolonifer, Trichoderma spp and Saccharomyces cerevisiae were confirmed to be Penicillium sclerotiorum, Diutina catenulata, Rhizopus* [7].

Fig 2: Processed cassava flex (known as Garri)

Production of Fermented Cassava Flour (Lafun/Fufu)

This fermented cassava flour is valuable food resource, commonly known in the Southwestern part of Nigeria as Lafun and in the southeastern part of Nigeria as Fufu. It is an energy giving food that is served during lunch time in both rural and urban centers. It is known as fermented cassava flour and popularly eaten in Nigeria. Its processing takes three to four days before it can be sieved to a moist cassava flour. The tubers are harvested from the farm, peeled and soaked in water for three to four days. The soaking allows for fermentation of the cassava which removes the potential poisonous cyanide content of the cassava and also help in preservation of cassava flour. Some microbes have been identified to help increase the fermentation process. Such as *Bacillus subtilis, Klebsiella sp, Candida tropicalis, Candida krusei some Lactobacillus plantarum* and *Leuconostoc plantarum* have been identified at the pH of 6.3+0.2 to 4.0+0.3 [38]. He also reported that *Bacillus subtilis,* and *Klebsiella sp* contribute to the rotting and softening of the soaked fleshy cassava tubers [7]. The soft tuber is mashed manually by crushing, the wooden fiber removed, the mash is sieved with a 0.2 mm sieve which separates the flour from the coarse fiber particles to form the fufu. While the lafun is prepared from the soft tuber which is manually mashed, the wooden fiber removed, and the mash is then sun dried. The dried products are milled into flour using plate mill and sieved to remove coarse fiber particles. The same process goes for fufu but without drying [38].

Production of Tapioca

It is another common local food made from cassava and sold in local markets in the rural part of southeastern Nigeria. This food also known as 'abacha' is eaten as snack or as lunch in a normal Nigerian setting. The cassava tubers freshly harvested from the farm, is peeled to remove the outer peel of the cassava tuber. The tubers are boiled and shredded or sliced into shapes that they are known for. The boiled sliced cassava tubers are then soaked in cold water for 8-24hrs depending on the cassava species. This is also part of the domestic activities that take place in riverine area where the sliced cassava tubers are soaked in the basket and kept in surface water body. After twenty-four hours soaking in water, the tapioca is removed and either dried under the sun or are preserved in cold water. However, the water will be removed and replace every six hourly. Therefore, the tapioca is consumed as either wet or dry snacks or is mixed with palm oil in water emulsion where sodium bicarbonate is used as an emulsifier and some local spices added to enhance flavor and taste [11, 12].

B. Industrial Uses

Cassava has been the source of a number of economically important industrial materials, for instance cassava is the major source of cellulose in paper; food and textile industries. The products obtained from commercial use of cellulose in paper industries include; toilet papers, kitchen towel, disposable napkins, handkerchiefs etc. In food industries cellulose from cassava is used as a stabilizer, emulsifier, thickeners and an anti-caking agent [14]. Cellulose from cassava is an important and available renewable resource for textile. Its physical and chemical modification reaction yield fiber of high commercial importance [15]. It has been reported that cellulose is the most abundant polymer on planet earth [31]. In recent times, cellulose has been used in production of several other products such as cellulose based bioplastic foams, diapers etc [27, 32]. Cassava starch is one of the oldest forms of product used in food, beverage, candy, chemical industries, glue, paper making, medicine and cosmetics. In food recipes, cassava starch is used as good additives, sweetener, and flavor. Cassava starch dextrin is used as good binder in cardboard paper, glue and adhesive tape. Cassava starch is also used as binder and as a disintegrating agent in drug (tablet) production. Used in molding tablets. In hair dressing salon, moose and thickener in shampoos are product of cassava starch.

Food Industry

Unprocessed cassava flour are used in bakery and pastry industries. Cassava flour has been shown to be healthier to use in bakery industry. In Nigeria, it has replaced the usual wheat flour.

i) Cassava Starch: The most important use of cassava in agro-industry is in starch production. This includes the use of different varieties of cassava tubers (bitter and sweet), used in the production of sweet and sour starch. The sweet starch is gotten after extraction process to ensure that it is separated from other components while the sour starch is gotten through fermentation following extraction. Sweet starch is known for its binding properties in the textile, paper and battery industry whereas sour starch is fully utilized in food industry [13]. Production of starch from cassava is done locally by soaking the peeled, grated cassava roots in water in order to separate the starch from the fiber, water is added to the mash to make a thin slurry. The slurry is sieved, dewatered and sun dried for 24 - 120hrs or by mechanized drying for six hours at 50oC [43].

ii) Livestock Feed: Serves as food in production of animal feed for pigs, cattle, sheep and poultry. Dried peels of cassava tubers serve as feed for sheep and goats. Also, raw or boiled tubers mixed in a mash with protein and mineral salt are used for feeding livestock [34]. In Nigeria, large quantities of peels are produced from peeling cassava tuber; however, these waste that are supposed to pose environmental challenge in the areas where they are produced are processed into valuable feeds. Cassava peel mash has been formulated and is now a viable industry that converts cassava waste into a safe livestock feed. Here, cassava peels are sundried grated and turned into high quality cassava peel mash. This product is an energy-rich fed and has other nutritional values close to maize. This has been used to feed poultry birds, pigs and the substantial reduction in maize replacement have been reported. Studies have shown that cassava leaves and tubers are abundant in protein which can be used as supplement in ruminant nutrition, especially in beef cattle, dairy cows, and buffalo [48, 50]. This product can be used as a feed supplement and as protein source in concentrates [18, 49]. Many local farmers add groundnut, crayfish, periwinkle etc to increase the protein content.

In Alcohol Production

Alcohol is an essential industrial chemical, produced through yeast metabolism. The fermentation process used in production of alcohol is an earliest exploit and it's considered as one of the first microbial process ever practiced by man. The conversion of cassava starch to ethyl alcohol involves two process of starch hydrolysis into glucose. This is done through the conversion of diluted glucose solution by actions of anaerobic yeast. This process includes washing, peeling, milling, cooking, saccharification, fermentation and distillation. Also, elsewhere in other countries of the world, cassava has been used to produce large tonnes of ethanol, for instance, [17], reported that China facilities has the capacity of producing 3000 tonnes of industrial grade ethanol from cassava annually. According to [4] reported that cassava holds more benefit when used for industrial production of ethanol. Furthermore, [4] reported using two yeast strains of saccharomyces cerevisiae to produce enzymatic ethanol in Nigeria. Alcohol has a wide application in chemical industries, used as a raw material in production of some chemicals such as glycol ethers, amines ethyl acetate, vinegar. It is also used as solvent for dyes, oils, wax, explosives and cosmetics [3].

C. Application of Biotechnology in Cassava Transformation

The use of biotechnology has helped resolve problems association with cassava production and enhancement through genetic engineering. This is done by improved agronomic traits achieved as a result of transgenic technology such as virus resistance, reduced cyanide content, improved biomass etc.

Resistance to Virus

The reduction in the yield of cassava production especially in developing nations is due to wide spread of cassava virus from one generation to another through its vines, stems and tubers.

i) Cassava Mosaic Disease (CMD) is a major disease associated with cassava and accounts for about 20-95% losses [24]. The cause of CMD have been linked with several cassava germiniviruses and their subviral pathogens such as African cassava mosaic virus (ACMV), Eastern ACMV and Indian CMV [35]. The use of transgenic technology in obtaining virus resistance cultivars have been of immense importance. The control of cassava vein mosaic virus promoter is done through the use of two strains of ACMV-Kenya (pILTAB9001 and pILTAB9002) carrying both wide type and mutant AC1 genes, and the Rubisco terminator, which facilitates the production of transgenic plant containing TMS560444 with high resistance to mosaic disease [8]. However, susceptibility of these transgenic plants to CMD infection in controlled field trial has been discovered. The use of enhanced anti-sensed RNA plants with elevated ACMV resistance that targets the viral mRNA of Rep (AC1), TrAP (AC2) and Ren (AC3) showed no symptom in transgenic clones after biolistic inoculation of ACMV at infection pressure of 100ng viral DNA plants [54]. Furthermore, the use of RNAi-mediated gene silencing approaches, siRNA, homologous to either the common region or AC1 in transgenic cassava plants suppressed the replication of African mosaic virus, which led to recovery after infection with ACMV [46].

ii) Cassava Brown Streak Disease (CBSD) is another major cassava disease in which the causative virus of the ipomovirus family (Mbanzibwa et al., 2009). Resistance cassava species have been developed via transfer of the virus coat protein or through interference of RNA (siRNA) [36].

iii) Cassava Bacteria Blight (CBB) disease or gum disease in which the causative organism Xanthomonas manihotis attacks the leaves of cassava. This causes the infected leaves to have angular, water-soaked spots along the veins, margins and tips. This disease occurs during high temperatures and rainy days. The use of transgenic technology have shown great changes in cassava gene after infection by this disease [26].

Pest Resistance

Cassava mealybugs, whiteflies, cassava green mites, and stem borers are the major insects that disturbs cassava cultivation while the nematodes that are parasitic to cassava are root knot nematodes. Cultivation of cassava with insect resistant genetic makeup could increase the yield and quality of the crop. Bt Cry proteins, protease inhibitors, α-amylase inhibitor and protein lectin which are insecticide proteins have proven to be useful in increasing insect resistance in transgenic cassava [30].

Improved Stress Resistance

The susceptibility of cassava to cold stress as a result of winter, snow, rain and freezing temperature is of concern due to decrease tuber yield which causes severe frostbite to cassava stem [25]. Cassava with high expression of C-repeat or dehydration-responsive element binding factor 3 gene have been developed to have resistance to low temperature controlled by CaMV 35S promoter has shown remarkable improvement to cold resistance in transgenic cassava [25]. Furthermore, cassava growth and yield is affected by sporadic drought in both tropical and subtropical regions, the use of SAG12 (leaf senescence induced promoter) in transgenic cassava for the expression of ipt gene, increases leaf life and enhances resistance to drought stress [55].

Reduced Cyanide Content

Antisense expression CYP79D1 and CYP79D2 gene of cytochrome P450 have been developed through the use of Arabidopsis leaf specific promoter [41]. The result showed that 60-90% of the cyanogenic glucoside level reduced drastically in transgenic leaves when compared to the control, with the roots having 99% decrease. Furthermore, it was observed that only 6% of the enzyme (hydroxynitrile lyase) is present in the root at transcript level, to that in leaves [51]. Over expression of this enzyme led to a reduction in the content of acetone cyanohydrin in roots thus enhancing the rate of detoxification. This is possible by cloning the cDNA of the gene coding for hydroxynitrile lyase between the CaMV 35S promoter and pea ribulose bisphosphate carboxylase terminal sequence which is transformed into MCol2215 [40].

D. Transgenic Cassava with Improved Nutritional Quantities

Transgenic Technology has proven to be of great important in the improvement of cassava in other to provide the necessary nutrient requirement for African population, especially those of the developing countries, as it is a major food consumed. Transgenic approaches has help in biofortification of the wild type cassava variety making it healthier for consumption. There are various ways in which transgenic technology has helped enhance the nutritional content of cassava of which includes; vitamin, mineral, protein and starch content etc.

Improved Vitamins A Content

Cassava, a dietary staple in many countries of the world especially in Africa, are not necessarily the most nutritious. It lacks most nutrients especially the essential micro-nutrient in diets of human and livestock animals. High vitamin A cassava have been developed through classical genetic technique. Vitamin A deficiency is still amongst the disorder responsible for the suffering in many developing nations of the world including African and Nigeria in particular [52]. However, this suffering can be alleviated by supplementing with more nutritious plant product into the cassava. The wild variety cassava usually consumed are deficit in β- carotene, the provitamin A. Vitamin A deficiency causes night blindness and it's a major nutritional disorder ravaging the whole world. To overcome this disorder, cassava has been genetically manipulated to produce β carotene in the cassava endosperm. The presence of β carotene in cassava is the reason for an orange coloration inside of the cassava tuber. The biosynthetic pathway for manipulation of cassava tuber through introduction of genes encoding the enzyme have been described. The coexpression of DXS and Crt B-encoded phytoene synthase in storage root to produce high yield of β-carotene in the storage root. In Nigeria, in 2016 a group called Harvest plus and its partners successfully developed and delivered varieties of vitamin A cassava to millions of farmers/ households in Nigeria and this variety of cassava is known as biofortified vitamin A cassava [21]. Presently biofortified vitamin cassava is been produced in 22 states of Nigeria while very low production of this varieties is been recorded in 11 states of the country. Studies have shown that the degradation rate of carotenoids investigated showed sun drying to be most detrimental to provitamin A level (44 - 73% degradation) in cassava and the least degradation of provitamin A in cassava was by oven drying (10-45) [9]. It has also been reported that the different processing methods of cassava including boiled, garri, fufu, fermented and non-fermented flour) reduced the beta carotene (precursor) from 30%-70% in garri. In Nigeria, the biofortified varieties of cassava are widely accepted as consumers are interested in the finished product (garri or flour etc). Many are still ignorant of information around the biofortification of cassava, however that it is solving the problem of hunger in the land. Presently the breeding of biofortified cassava have been scaled up at international center for tropical Agriculture (IITA), National Roots Crops Research Institute (NRCRI) etc.

Enhancement of Mineral Content

Strategic genetic engineering has been employed in order to improve the concentration of minerals particularly iron and zinc in cassava roots [20]. Overexpression of A. thaliana (At) zinc transporters AtZIP1 and AtMTP1 showed increased zinc concentrations in roots but not in shoots of transgenic plants [16]. According to [29] reported that overexpression of A. thaliana vacuolar iron transporter (VIT1) in cassava gave a high level of iron concentration in roots when compared to those of non-transgenic cassava plants (controls). Also, coexpression of mutant A. thaliana iron transporter (IRT1) and ferritin (FER1) generates transgenic cassava plants that accumulate iron and zinc in roots in substantial amounts [23].

Improved Protein Content

Cassava tubers have minute protein concentration (about 1% FW), thus reducing its nutritional value due to low concentrations of essential amino acids necessary for growth and development of children. Such amino acids include; lysine and leucine as well as methionine and cysteine (sulfur essential amino acids) [28]. Report, on the concentration of protein composition in cassava tuber TMS60444, showed low concentration of total hydroxyproline, cysteine, methionine, tryptophan, tyrosine and histidine. With the glutamic acid and aspartic acid having at least twice the amount of the other amino acid [45]. Sayre et al [39], experiment proved that cyanogens provide low nitrogen substrates for the synthesis of amino acid in cassava tubers, hence possible improvement in amino acid and enhancement of overall protein biosynthesis can be achieved through the manipulation of cyanogenic glucoside metabolism in cassava. Also, overexpression of hydroxynitrile lyase, responsible for conversion of acetone cyanohydrin to cyanide leads to overall increase in protein content [29].

Improvement in Starch Quality

Cassava starch quality is of great economic value. It has up to 70% to 80% Amylopectin content and 20% to 30% amylose which is dependent on the genotype and growth environment [22]. The quality of starch produced for various industrial purposes (pharmaceutical, chemicals and paper making) is dependent on the ratio of amylose to amylopectin. The production of starch is determined by three (3) enzymes (AGPase, starch synthase and starch branching enzyme [6]. Ihemere [19] reported that improved AGPase activities facilitate the conversion of sugar to starch leading to increased starch quality.

E. Biotechnological Transformation of Cassava for Food Sustainability in Nigeria

As the problem of food insecurity keeps unfolding, many people believe that its solution in Africa and Nigeria in particular, will come from their embracing genetically modified food; modifying plants with new gene yields, new traits which are valuable in the society. The purpose of transforming these plants is to improve the performance of the plants in the field and also the development of new products with desired character for sustainability over a long term. Such characters as; resistance to environmental stresses on plant (biotic or abiotic stress), improvement of crop yield, improvement of nutritional qualities of crops are critical to improvement especially in a tropical country like Nigeria.

Insect pest has always been the reducing factor in agricultural yields of farmers particularly in a developing-countries like Nigeria where, their climatic conditions support the growth and multiplication of pest organisms. Such pests include grasshopper, aphis, weevils and the larval stages of butterfly etc. In Nigeria, an estimate of 20% and 40% loss and reduction in agricultural produce is considered to be significantly high due to low agricultural productivity in different regions of Africa [1]. Insects and other pests are major threat to cassava plants especially in cassava production [5], which also affect cassava farming and storage directly and indirectly [47]. Insects are responsible for 15 -100 % and 10- 60 % of the pre- and post-harvest losses of cassava in a developing country like Nigeria [53]. Most of the insects that damage cassava in Nigeria belong to the following order of insects: Lepidoptera (moths and butterflies), Coleoptera (beetles), orthopteran (grasshoppers; Zonocerus varigatus) and homoptera (Aphids) etc. Patil [36] reported that Aphids (Aphis craccivora) eat up the leaves of the cassava plant, pod borer (Maruca vitrata) and pod formation, a complex of pod sucking bugs formed inside of the stem, the weevil (Callosobruchus maculatus) and termites which attack the tubers and reduce the market values of the farm products.

The categories of insect pests attacking cassava have been reported and they include; field pests such as stalkborer (Busseola fusca), leafhoppers (Cicadulinambila) and mole crickets (Gryllotalpidae) also eat up the stem of cassava plant. Insect pest infestation is a serious problem in Africa, and it reduces both economic and market values of crops. Chemical methods (use of pesticides/herbicides) have been a regular means of eliminating these pest organisms in agricultural farm. A recent study has shown that glyphosate application caused disturbance in an important soil fungus (Aspergillus nidulans) at cellular levels at doses far below the recommended agricultural application rate [27]. Occasionally farmers use conventional breeding technique (selective method), which involved traditionally selecting plant varieties that are resistant to pests. It also involved combining resistance gene with high quality crops genes to achieve the resistance to pest organisms. Transgenic plants with resistance transgene have been developed and this has helped to protect plants from pest attack. Soil bacterium such as Bacillus thuringiensis (gram negative), is known to produce toxic protein that kills insects. The protein referred to as insecticidal crystalline protein (ICP) has been inserted into important crop plants such as potato, tomato, corn etc. and these plants synthesize the toxin. When the crystal (Cry) proteins have been ingested by insects grazing on the transgenic plant, the protoxin gets activated within the gut by a combination of alkaline pH (7.5 to 8.5) and proteolytic enzymes. The toxin gets to the membrane of the gut epithelial cell of the insect. This forms an ion channel through which there occur an excessive loss of cellular energy. As a result of that, the insect will not be able to take in food, becomes dehydrated and dies. Recent study has shown transgenic cassava plant over-expressing Cry1Aa protein in cassava to reduce the efficacy of a Lepidoptera (H. armigera) feeding on the wild cassava leaves. The study showed a high expression of Cry1Aa in the wild type cassava causing lethal consequences in larval stages of Helicoverpa armigera, compared to the normal growth and development of adult and pupa stage fed with the same cassava wild leaves [10]. The need to improve cassava plant through expression of Bt genes for resistance to diseases is still been negotiated and discussed. The skepticisms are as a result of the fact the Nigeria seriously lack the adequate control to monitor the risk associated with genetically modified crops. There is no testing of food materials and products for gene manipulations.

Higher plants naturally produce proteinase inhibitor, which are found to possess insecticidal property and provides protection to plants against insect pest attack. This gene has been inserted into crop plant to protect it against herbivorous insects. Example of such inhibitor gene include; cowpea trypsin inhibitor gene which is obtained from cowpea plant growing in Africa. These insecticidal proteins are toxic to insects in the order Lepidoptera, Orthoptera, Coleoptera, etc. However, no report has been seen on the use of proteinase inhibitors to provide protection in cassava plant in Nigeria. With the unlimited distribution of cassava resources and nutrient availability, there will be stability and food security in the sense of sustaining processes that contribute to ecosystem services.

Microorganisms (bacteria and fungi) are the major organisms reducing agricultural productivity worldwide. They impact negatively on products, thereby reducing its nutritional and economic value. Diseases of these crops may manifest even in post-harvest quality of the crop which is a great loss to farmers and contribute to driving food insecurity. For increased yield and environmental concerns, researchers have discovered transgenic expression of genes that can confer disease resistance to plants. Many transgenic techniques used in developing disease resistance in plants include; the transfer of antimicrobial proteins, antimicrobial metabolites (glucosinolates and stilbenes), disease resistance genes from other species of plants and components of signal transduction mechanisms. The disease resistance gene RB is a classic nucleotide-binding site leucine-rich repeat (NBS-LRR) disease resistance gene that was map-based cloned from the potato relative Solanum bulbocastanum [42]. Resistant cassava species have been developed by transferring the virus coat protein or through RNA (siRNA) interference Patil [29]. Protecting agricultural plants from microbial and viral infections tend to increase the yield of crops and fruits which farmers depend on for their income.

In many occasions, harvested agricultural product damage before it gets to the consumers, the rate of damage as the products are taken to the market is much. In Africa, spoilage of agricultural products is attributed to environmental factors such as excessive heat, lack of storage facilities, no good roads and transportation system. However, the products are supposed to get to the consumers in a palatable and attractive form. In Nigeria, cassava is mainly produced in the southern part of the country, this crop plant is always planted in a mixed cropping system with such crops as, maize, yam, melon and other vegetables. However, cassava farms are damaged by flood, drought and pests such as insect and rodent pests. These factors affect productivity and being the staple food of the populace, prepared as snacks and main food. Cassava tubers, which is the main target farm product are rotten before harvest, thereby reducing the farmers yield, and contributing to food insecurity. Sometimes, the products are transported to the different parts of the country, a lot of them get damaged and lose their market value. Many countries of the world try to control environmental factors such as controlling the amount of oxygen and reducing the temperature. Cassava is known for its ability to strive under poor environmental conditions, however, post-harvest physiological deterioration (PPD) is known for its severe effect on cassava storage and utilization. This can be genetically improved using several cassava germplasm or transgenic technologies, the proteins and enzymes affecting PPD, most of which are involved in signal transduction, ROS, cell wall repair, programmed cell death, metabolite transport, signal transduction, and a series of biological processes [37]. Research has shown that PPD process can be interfered with via the control of ROS-scavenging activities. The major enzymes involved in these activities are ascorbate–glutathione cycle, the glutathione– peroxidase cycle, and the peroxidase–oxidoreductase cycle. These enzymes when combined with superoxide dismutase, generate univalent, bivalent, and trivalent overexpression or RNAi vectors to transform cassava.

Biotechnology is already contributing a lot in solving the problems emanating from environment and climate change for increase productivity and sustainability.

African countries need adequate and nutritious food to reduce malnutrition and mineral deficiencies. Most of their staple food lack essential minerals, those essential amino acids that are supplied to human body through dietary supplement. Cassava tubers have minute protein concentration (about 1% FW), thus reducing its nutritional value due to low concentrations of essential amino acids; lysine and leucine as well as methionine and cysteine (sulfur essential amino acids) [28]. Report, on the concentration of protein composition in cassava tuber TMS60444, showed low total concentrations of hydroxyproline, cysteine, methionine, tryptophan, tyrosine and histidine. However, Sayre [39], demonstrated that cyanogens provide reduced nitrogen substrates for amino acid synthesis in cassava tubers, hence manipulation of cyanogenic glucoside metabolism in cassava can possibly increase root amino acid and promote total protein biosynthesis. Also, overexpression of hydroxynitrile lyase, responsible for conversion of acetone cyanohydrin to cyanide leads to overall increase in protein content [29]. Furthermore, a deficiency in vitamin A, a major nutritional disorder affecting children worldwide, and lack of vitamin A causes night blindness. It is estimated that over 100 million people in Sub-Saharan Africa are at higher risk of going blind due to vitamin A deficiency and in Uganda and Mozambique, between 38 and 68% of all the children are affected. Vitamin A is an essential nutrient required for maintaining immune function, eye health, vision, growth and survival in human beings [52]. Scientist have developed a variety of cassava which produce roots rich in ß-carotene, through the manipulation biosynthetic pathway of cassava tuber by introduction of genes encoding the enzyme. The co-expression of DXS and Crt B-encoded phytoene synthase in storage root to produce high yield of β-carotene in the storage root. The presence of beta-carotene in cassava gives it a yellow/orange color and beta-carotene a precursor for vitamin A. This is a breakthrough that gives Africa hope as nutritional disorder is ravaging the continent. Iron deficiency is also a global problem affecting children under the age group of 6-to-24 months and impairing the mental development of 40% to 60% of the developing world's children. More severe cases of iron deficiency (anemia) causes the death of an estimated 50,000 young women annually in addition to pregnancy and childbirth [36]. Other scientists have added a protein that binds iron (Ferritin) to cassava. This new cassava is produced to improve iron deficiency resulting in anemia which increase the susceptibility to infections in people and impaired learning ability in children. Also, Arabidopsis thaliana has been genetically modified to produce ten-fold higher vitamin E (tocopherol) than the native plant.

IV. CONCLUSION

Cassava is known as a staple food and one of the major food security crop of developing countries because of its ability to survive extreme environmental conditions. In Nigeria cassava is produced in over twenty (20) states and use for various purposes because of its high carbohydrate and energy content, making it the most consumed. It has also served as food for livestock animals when mixed with proteins and minerals. However, due to its poor nutitional quality is considered food of the poor. Thus, The use of biotechnological approaches has helped to enhance cassava production as well as it biofortification through the use of transgenic technology for food sustainability.

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