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Article · January 2019

DOI: 10.5829/idosi.ajn.2019.34.46

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Academic Journal of Nutrition 8 (3): 34-46, 2019
ISSN 2309-8902

DOI: 10.5829/idosi.ajn.2019.34.46

Medicinal, Nutritional and Anti- Nutritional Properties of Cassava (*Manihot esculenta*): A Review

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Abstract: The use of plant foods for therapeutic purposes represents one of the biggest human uses of the natural flora of the world. Cassava is any of several tropical plants belonging to the genus Manihot, of the family *Euphorbiaceae* and species esculenta or dulcis. They exist in varieties as *Manihot esculenta* (Bitter cassava) and *Manihot dulcis* (Sweet cassava) cultivated for their tuberous roots, which yield important food products. It is also used in the performance of various rituals and rites as well as for therapeutic purposes. *Manihot esculenta* Crantz, popularly known as cassava is one of the plants with various medicinal properties. Many studies showed that, due to presence of different phytochemicals cassava become remedy for different ailments like diabetes, celiac diseases, bone and neurological health, cardiovascular diseases, prostate problems and allergies, GIT problems and blood pressure etc., given that, it is important to remember cassava can be very poisonous if not prepared, processed, or cooked properly, Cassava produces cyanide and other toxicants, which are extremely poisonous compound to humans. The commonly occurring anti-nutrients in plants include; cyanide, Phytates, nitrates and nitrites, phenolic compounds and oxalates among others. As much as cassava contains various beneficial nutrients (carbohydrates, vitamins and minerals, proteins, fiber and essential amino acids), it also has anti-nutritional and toxic substances, which impair nutrient uptake and absorption of nutrients. However, it has been documented in that various processing methods reduce the levels of some of these toxic substances in cassava. *Manihot esculenta Crantz* is not so commonly used in herbal medicine, but indigenous people do employ it for various purposes. Because some of its potentially toxic components, sometimes it is considered as non-edible and toxic in various parts of the world. But, it is definitely one of the most useful medicinal plants. Various phytochemicals presents in this plant, numerous medicinal uses and detoxification mechanism of this neglected plant have been highlighted in this review.

Key words: Anti-nutrients · Cassava · Medicinal value · Nutrients

INTRODUCTION

Since ancient times of civilization, people of the world have been relying on medicinal plants, plant extracts and their natural constituents as either prophylactic or therapeutic remedy to restore and maintain health or as an alternative treatment for various diseases including analgesia and inflammatory process of diverse organs [1, 2]. Despite the immense technological advancement in modern medicine, many people in Africa (Approximately 75% of the population) still rely on traditional healing practices and medicinal plants for their daily healthcare needs [3]. Similarly Ethiopian traditional medicine is composed of a number of specific skills, namely; the use of plants, animal products and minerals as well as magic and superstition. Though most practices and treatments in herbal medicine require specialists or professionals which are referred generally to as herbalists, to use plants which are common in Ethiopia [4]. Even though, there is significant role of medicinal plants in supporting the Ethiopian national primary health care, little work has so far been made to properly document the associated knowledge and promote its practices. On the other hand, medicinal plants and the associated knowledge are being

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seriously depleted due to deforestation, environmental degradation and acculturation that have been taking place in the country for quite a long time. So, urgent ethno botanical studies and subsequent conservation measures are needed to salvage the medicinal plants and the associated knowledge from further loss [5].

Among medicinal plants which are used so far in ancient times, cassava (*Manihot esculenta* Crantz) is one which is a dicotyledonous plant, belonging to the family *Euphorbiaceae* [6]. The crop is an important source of carbohydrate for humans and animals, having higher energy than other root crops, 610 kJ/100 g fresh weight in addition to remedy for various inflammatory, analgesic and carcinogenic conditions. Cassava is also significantly rich in calcium, manganese, beta carotene, vitamin C and vitamin A. In spite having toxic cyanide, cassava is remedy for number of ailments if prepared properly; such as digestive disorders (Gastritis, gastroduodenal ulcer, constipation and colitis), liver disease, celiac disease and diabetes [7]. Therefore, the objectives of this paper are to review on medicinal properties, nutritional composition, anti-nutritional components and detoxification methods of cassava (*Manihot esculenta*).

Medicinal Values of Cassava: Plants with various medicinal properties have been source of attraction for many scientists all over the world since thousands of years. Millions of plants have been studied extensively since ancient times for various phytochemicals and their possible medicinal uses in various disease conditions in human beings. Even modern day treatment strategies do not underestimate potential of herbs for various chronic illnesses [8]. Recently there has been a tremendous increase in the use of plant based health products in developing as well as developed countries resulting in an exponential growth of herbal products globally. In the present era of drug development and in discovery of newer drugs, molecules of many plant products are evaluated on the basis of their traditional uses. *Manihot esculenta Crantz*, popularly known as cassava is also one of these plants with various medicinal properties [9].

Effects of Cassava on Cardiovascular Diseases: One of the most valuable mineral contributions of tapioca is iron. Iron is essential for the normal functioning of the human body and perhaps its most significant roles are in the creation of new red blood cells. Together with copper, which tapioca also contains, iron increases the amount of red blood cells in the body, thereby preventing anemia and related conditions. With more red blood cells being produced by the body, peripheral organ systems and extremities are guaranteed a healthy flow of blood and oxygen to keep those cells healthy and operating at their optimal levels. Cellular re-growth and maintenance is improved, which means that wound healing and energy levels are also increased [10].

Effect of Cassava on Gastrointestinal Tract Problems: One of the other bonuses of tapioca is the wealth of dietary fiber it contains. Fiber has been directly linked to improving a number of conditions within the human body, but the most obvious is in terms of digestion. Fiber 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. Furthermore, fiber 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 like heart attacks and strokes [11].

Effect of Cassava on Blood Pressure: Tapioca also contains potassium, yet another essential mineral that the human body requires. Potassium is a vasodilator, meaning that it reduces the tension and stress of blood vessels and arteries. This can increase the flow of blood to parts of the body and reduce the strain on the cardiovascular system. This means a reduction in atherosclerosis and a much smaller chance of blood clots getting stuck and causing fatal events like heart attacks or strokes. Furthermore, potassium is key for fluid balance in the body and when it is in proper balance with sodium, all of the fluid exchanges in the body can be smooth, further boosting metabolic efficiency and energy [12].

Effect of Cassava on Celiac Disease: Absence of the allergenic protein -- gluten -- makes cassava flour a good substitute for rye, oats, barley and wheat. Persons diagnosed with celiac disease and other gluten-based allergies can find relief in consuming foods made using 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 [13].

Bone and Neurological Health: Tapioca is a rich source of vitamin K, calcium and iron, all of which play important roles in the protection and development of bones. Bone mineral density decreases as we age, resulting in conditions like osteoporosis, osteoarthritis and general weakness and lack of flexibility. If tapioca is regularly consumed, then our bones can be protected and developed and also maintained as we get older. The wealth of vitamin K does more than promote osteotrophic activity, it is also important 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 often occurs due to a lack of activity or mental stagnation; vitamin K keeps neural pathways active and engaged and free of free radicals that can cause a breakdown of brain tissues [14].

Effect of Cassava on Prostate Problems and Allergies: The 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 and a few clinical tests have shown cassava to be effective in treating prostate problems ranging from infections and swelling to cancer [15]. 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 and better evidence is available [16].

Effect of Cassava on Diabetes: In modern medicine no satisfactory effective therapy is still available to cure diabetes mellitus, which is a syndrome resulting from a variable interaction of hereditary and environmental factors and characterized by abnormal insulin secretion (Type- 1) or insulin receptor or post-receptor (Resistance, Type- 2) events affecting metabolism involving carbohydrates, proteins and fats in addition to damaging â-cells of pancreas, liver and kidney in some cases. Several attempts have been made to tackle hyperglycemia and comorbidities (Cardiovascular, renal, hepatic, ophthalmic, neurological and osteopathic-, endothelial- and sexual-dysfunction, etc.) that come with increased blood glucose level. To this effect drugs like sulfonylurea that stimulate insulin secretion by the islets and α-glucosidase inhibitors that augment glucose utilization and suppress glucose production have been developed. Despite the limited efficacy of these therapies, it is also not devoid of side effects, therefore necessitating the search for new classes of drugs to combat this disorder. To this effect, many substances from plant source have been found to possess anti-diabetic activity with minimal side effects and the search is on-going [17].

There is a trend towards using natural products to control hyperglycemia and associated pathologies. Cassava has been rediscovered as a medicinal agent. Cassava has been reported to have a broad spectrum of biological activities; the anti-oxidant, oxygen radical scavenging activity of cassava (And its extracts) is mainly due to the presence of phenolics and flavonoids. The beneficial effects of cassava in diabetes have been confirmed by a number of studies in experimental animals [7].

Nutritional Value of Cassava: Composition of cassava depends on the specific tissue (root or leaf) and on several factors, such as geographic location, variety, age of the plant and environmental conditions. The roots and leaves, which constitute 50% and 6% of the mature cassava plant, respectively, are the nutritionally valuable parts of cassava [18]. The nutritional value of cassava roots is important because they are the main part of the plant consumed in developing countries. In Table 3, the proximate mineral and vitamin compositions of cassava roots and leaves are reported.

Nutritional Value of Cassava Roots

***Macronutrients*:** Cassava root is an energy-dense food. In this regard, cassava shows very efficient carbohydrate production per hectare. It produces about 250000 calories/hectare/d, which ranks it before maize, rice, sorghum and wheat [18]. The root is a physiological energy reserve with high carbohydrate content, which ranges from 32% to 35% on a fresh weight (FW) basis and from 80% to 90% on a dry matter (DM) basis. Eighty percent of the carbohydrates produced are starch [19]. 83% is in the form of amylopectin and 17% is amylase [20]. Roots contain small quantities of sucrose, glucose, fructose and maltose [21].

Cassava has bitter and sweet varieties. In sweet cassava varieties, up to 17% of the root is sucrose with small amounts of dextrose and fructose [17, 18]. Raw cassava root has more carbohydrate than potatoes and less carbohydrate than wheat, rice, yellow corn and sorghum on a 100-g basis (Table 1). The fiber content in cassava roots depends on the variety and the age of the root. Usually its content does not exceed 1.5% in fresh root and 4% in root flour [19]. The lipid content in cassava roots ranges from 0.1% to 0.3% on a FW basis.

Table 1: Maximum recorded yield and food energy of important tropical staple crops (Source: [25]

Crop	Annual yield (tons/hectare)	Daily energy production (kJ/hectare)
Fresh cassava root	71	1045
Maize grain	20	836
Fresh sweet potato root	65	752
Rice grain	26	652
Sorghum grain	13	477
Wheat grain	12	460
Banana fruit	39	334

Table 2: Amino acid profile of cassava [19]

	Content in roots			Content in leaves		
Amino acid	% wet weight	% dry weight	% protein	% wet weight	% dry weight	% protein
Arginine	0.10	0.29	11.0	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

This content is relatively low compared to maize and sorghum, but higher than potato and comparable to rice. The lipids are either non polar (45%) or contain different types of glycolipids (52%). The predominant fatty acids are palmitate and oleate [22]. The protein content is low at 1% to 3% on a DM basis and between 0.4 and 1.5 g/100 g FW [23].

In contrast, maize and sorghum have about 10 g protein/100 g FW. The content of some essential amino acids, such as methionine, cysteine and tryptophan, is very low (Table 2). However, the roots contain an abundance of arginine, glutamic acid and aspartic acid [19]. About 50% of the crude protein in the roots consists of whole protein and the other 50% is free amino acids (Predominantly glutamic and aspartic acids) and non-protein components such as nitrite, nitrate and cyanogenic compounds. The presence of cyanogenic compounds, which predominate in bitter varieties and processes to reduce them were recently reviewed by Montagnac *et al*. [24].

Minerals and Vitamins: Cassava roots have calcium, iron, potassium, magnesium, copper, zinc and manganese contents comparable to those of many legumes, with the exception of soybeans. The calcium content is relatively high compared to that of other staple crops and ranges between 15 and 35 mg/100 g edible portion. The vitamin C (Ascorbic acid) content is also high and between 15 to 45 mg/100 g edible portions [18, 14]. Cassava roots contain low amounts of the B vitamins, that is; thiamin, riboflavin and niacin and part of these nutrients is lost during processing. Usually the mineral and vitamin contents are lower in cassava roots than in sorghum and maize. The protein, fat, fiber and minerals are found in larger quantities in the root peel than in the peeled root. However, the carbohydrates, determined by the nitrogen-free extract, are more concentrated in the peeled root (Central cylinder or pulp) [19].

Nutritional Value of Cassava Leaves

Protein and Carbohydrates: The nutrient composition of cassava leaves varies in both quality and quantity depending on the variety of cassava, the age of the plant and the proportional size of the leaves and stems [19]. Cassava leaves are rich sources of protein, minerals, vitamins B1, B2 and C and carotenoids [26]. Cassava leaf protein ranges from 14% to 40% of DM in different varieties [27]. The crude protein content is comparable to that of fresh egg (10.9 g/100 g) and the amino acid profile of cassava leaf protein is well balanced compared to that of the egg [28] except for methionine, lysine and may be isoleucine. Furthermore, cassava leaves have an essential amino acid content higher than soybean protein and FAO's recommended reference protein intake [18]. The carbohydrate content in cassava leaves (7 to 18 g/100 g) is comparable to that of green-snap beans (7.1 g/100 g), carrots (9.6 g/100 g), or green soybeans (11.1 g/100 g) and it is higher than those of leafy vegetables such as green leaf lettuce (2.8 g/100 g). The carbohydrates in cassava leaves are mainly starch, with amylase content varying from 19% to 24% [19].

Minerals and Vitamins: Cassava leaves are rich in iron, zinc, manganese, magnesium and calcium [10]. The following variations in mineral content for cassava leaf meal (CLM) have been reported: from 61.5 to 270 mg iron/kg DM, 30 to 63.7 mg zinc/kg DM, 50.3 to 263 mg manganese/kg DM, 6.2 to 50 mg copper/kg DM, 2.3 to 3 g sulfur/kg DM, 2.6 to 9.7 g magnesium/kg DM, 0.4 to 16.3 g calcium/kg DM and 8 to 16.9 g potassium/kg DM [29, 30].

Cassava leaf meal is rich in iron in comparison with liver (121 mg/kg FW) and egg yolk (58.7 mg/kg FW), although the iron from plant origin is generally less bioavailable than iron from animal food sources. Iron and zinc content in cassava leaf meal are comparable to those reported for sweet potato leaves and peanut leaves. Calcium content is comparable to those of peanut and broccoli and magnesium content surpasses that of broccoli but is below those of peanut and sweet potato. Thus, mineral content of cassava leaf meal is comparable with that of other leaves [10].

The vitamin content of cassava leaves is richer in thiamin (Vitamin B1, 0.25 mg/100 g) than legumes and leafy legumes, except for soybeans (0.435 mg/100 g). The leaves have more thiamin than several animal foods including fresh egg, cheese and 3.25% fat whole milk. The riboflavin (Vitamin B2) content of cassava leaves (0.60 mg/100 g) surpasses that of legumes, leafy legumes, soybean, cereal, egg, milk and cheese. The niacin content (2.4mg/100 g) is comparable to that of maize (2 mg/100 g) and surpasses those reported for legumes and leafy legumes, milk and egg. The vitamin A content of cassava leaves is comparable with that of carrots and surpasses those reported for legumes and leafy legumes. The vitamin C content (60 to 370 mg/100 g) of cassava leaves is high compared to values reported for other vegetables. Thus, the overall vitamin content of the leaves is comparable and in certain cases better than those reported for most legumes, leafy legumes, cereals, egg, milk and cheese [31].

Fiber: The fiber content of cassava leaves is high compared to the fiber content of legumes and leafy legumes and ranges between 1 and 10 g/100 g FW. Dietary fiber is considered part of a healthy diet and can reduce problems of constipation. Although recent evidence is mixed, fiber may help prevent colon cancer [32]. The rich fiber of cassava may assist intestinal peristalsis and bolus progression but, if fiber content from any source is too high, it will have negative effects in humans. Fiber can be a nutritional concern because it can decrease nutrient absorption in the body. Excess fiber will increase fecal nitrogen, cause intestinal irritation and reduce nutrient digestibility, in particular protein digestibility [31].

Anti-Nutritional Properties of Cassava

Anti-Nutrients in Cassava Leaves and Roots: Despite the many benefits of eating tapioca in various forms, it is important to remember that cassava can be very poisonous if not prepared, processed, or cooked properly. Cassava produces cyanide, which is an extremely poisonous compound to humans and animals. Therefore, while tapioca that you buy in a store is perfectly healthy to eat, don't attempt to process or eat tapioca grown or found in the wild, unless you are instructed by someone who is very familiar with a healthy way of processing it [33].

Anti-nutrients are also referred to as nutritional stress factors. These factors may either be in the form of synthetic or natural compounds and they impede nutrient absorption. The commonly occurring anti nutrients in plants includes; cyanide, phytates, nitrates and nitrites, phenolic compounds and oxalates among others. As much as cassava contains various beneficial nutrients, it also has anti-nutritional and toxic substances, which impair nutrient uptake and absorption of nutrients. However, it has been documented in that various processing methods reduce the levels of some of these toxic substances in vegetables [34].

Generally Cassava contains anti-nutrients, such as phytate, nitrate, polyphenols, oxalate and saponins that can reduce nutrient bioavailability. However, some of these compounds can also act as anti-carcinogens and antioxidants depending on the amount ingested. Phytate interferes with the absorption of divalent metals, such as iron and zinc, which are essential nutrients. The aqueous and ethanolic extracts of raw cassava tuber contain alkaloids, flavonoids, tannins and

Table 3: Nutritional composition of cassava roots and leaves Source: [23]

Proximate composition	Cassava roots	Cassava leaves
Food energy (kcal)	100-149	91
Moisture (g)	45.9-85.3	64.8-88.6
Dry weight g)	29.8-39.3	19-28.3
Protein (g)	0.3-3.5	1.0-10.0
Lipid (g)	0.03-0.5	0.2-2.9
Total carbohydrate (g)	25.3-35.7	7-18.3
Dietary fiber(g)	0.1-3.7	0.5-10.0
Ash (g)	0.4-1.7	0.7-4.5
Vitamins		
Thiamin (mg)	0.03-0.28	0.06-0.31
Riboflavin (mg)	0.03-0.06	0.21-0.74
Niacin (mg)	0.6-1.09	1.3-2.8
Ascorbic acid (mg)	14.9-50	60-370
Vitamin A (μg)	5.0-35.0	8300-11800
Minerals		
Calcium (mg)	19-176	34-708
Phosphorus (mg)	6-152	27-211
Iron (%)	0.3-14.0	0.4-8.3
Potassium (%)	0.25-0.72	0.35-1.23
Magnesium (ppm)	0.03-0.08	0.12-0.42
Copper (ppm)	2.00-6.00	3.0-12.0
Zinc (ppm)	14.00-41.00	71.0-249.0
Sodium (ppm)	76.00-213.00	51.0(177)
Manganese (ppm)	3.00-10.00	72.0-152.0

anthocyanosides, anthraquinone, phlobatinnins and saponins but, do not contain cardiac glycosides. The cassava leaves contain lot of antinutrients, such as tannins, oxalate, phytate and trypsin inhibitors [35]. Cassava leaves are nutritious but it contains more anti-nutrients that cause toxicity unless processed [36].

Phytates: Phytate is an anti-nutrient that controls the intracellular signaling and forms the phosphate storage part in plant seeds; although it binds proteins and minerals in the gastrointestinal tract making them unavailable for absorption and utilization by the body. In particular, phytate has a binding effect on multivalent metal ions, including zinc, iron and calcium, all of which are important nutrients. This leads to formation of salts that are highly insoluble and minerals that are less bioavailability [37].

Tannins/Phenolics: Flavonoids form a set of compounds that are referred to as polyphenolics, such as tannins, which are anti-nutritional agents. Data on polyphenols found in cassava leaves is expressed by researchers as tannin equivalents while employing a non-specific assay [33, 38]. Polyphenols, which are antioxidants, bind various minerals in food, reducing its bioavailability. In addition, they impair the functionality of digestive enzymes, thus slowing digestion and in some cases cause proteins precipitation [39]. The levels in plants vary and may be influenced by factors like; germination, storage and processing time. Increase phenolic compounds levels are known to decrease fertility among women of reproductive age by altering the levels of hormones, hence affecting the early pregnancy stages [40].

Cyanide: The cyanide, which occurs as cyanogenic glucosides, is a toxic compound that has been associated with adverse health outcomes among humans. The level of cyanide in cassava surpasses 10 mg/kg dry weight, which is the recommended maximum consumption level by the World Health Organization and the Food and Agricultural Organization. This makes cassava leaves highly toxic for consumption by humans. The content of cyanide in cassava roots is much lower (10 times lower) as compared to the leaves, an aspect that explains its utilization for methodological standardization [41]. The level of cyanide is cassava is defined by the type of cassava of reference, with each variety exhibiting different levels of this toxic compound. Excessive intake of cyanide is known to cause cretinism and goiter which are associated with iodine deficiency [42]. 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 [43]. As such, prior to consumption, it is important for cassava leaves to be properly processed in view of reducing the content of cyanide [44].

Oxalates: Oxalates are di-carboxylic acids that are present in plant-based foods such as cassava, which have a negative impact on the bioavailability of magnesium and calcium. These anti-nutritional agents bind calcium, leading to formation of crystals or excretion through urine. The crystals that form (Calcium oxalate) majorly contribute to kidney stones. It is highly advisable to reduce oxalates intake and promote the intake of calcium among individuals who are risk of kidney stones [45]. Cassava leaves have an oxalate concentration of between 1.35 and 2.88 g/100 g of total dry weight [33].

Less attention had been given towards the importance of the levels of oxalates in foods until recently, as it was believed that only 10% of the calcium excreted daily was due to dietary calcium [45]. The impact that oxalates have on the health of humans is highly dependent on the calcium available and the oxalate levels consumed. According to Wobeto *et al.* [33] cassava's calcium-to-oxalate ratio is a high of 5, which surpasses the

Table 4: The anti-nutrient levels of *Manihot esculenta* in mg/100 g of wet weight

Manihot esculenta	Phytates	Oxalates	Tannins	Cyanide	Nitrates
	191.25	15.74	0.65	25.69	3.58

recommended 0.44%, below which calcium uptake is endangered. As such, the level of oxalates in cassava leaves have 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. Other anti-nutrients including nitrates, phytates, oxalates, polyphenols and saponins also reduce the bioavailability of nutrients. The anti-nutrient compounds also act as antioxidants and anti-carcinogens depending on amounts consumed [31].

Nitrates and Nitrites: Nitrates occur naturally in most soils and water sources; hence they are taken up by growing plants. Leafy vegetables are the main contributors of nitrates in diets and contribute about 75% of the total foods ingested. Nitrates in themselves are not toxic at the levels present in most foods but the toxicity occurs when the nitrates are reduced to nitrites [46]. When high levels of nitrates in vegetables are ingested, they are changed to nitrite. This can result in the development of blue-baby disease, metheamoglobinemia, or cancer [47]. However, since nitrates and nitrites are water soluble, some amounts may be lost through leaching during the preparation process. Further, most of the nitrites present are oxidized to nitrate and upon cooking, they leach out of the vegetable [48]. Green leafy vegetables with increased levels of nitrates include; spinach, radishes, lettuce, beets and celery, among others [49].

Detoxification Properties of Cassava

Detoxification of Cassava Cyanogens

Biotechnology and Conventional Breeding: The presence of toxic cyanogenic glycosides in cassava constitutes a critical limiting factor to its use, together with other considerations such as deficiency in some essential nutrients and high deterioration rate. Detoxification through breeding/genetic engineering and processing offers an opening to scaling this debacle that confronts economic and social prospects of the plant. This reduces the exposure to cyanogenic compounds and thus lowers or eliminates the risk of cyanide intoxication [50]. Autolysis of linamarin is extensively relied on in detoxifying cassava (especially during processing) for human consumption. This is triggered by maceration or cell disruption, which results in bringing linamarase into contact with the glycosides and hydrolyses them. The activity of linamarase, however decreases a few days after harvest [51]. The reasons responsible for this lowered activity is not certain, but has been related to the formation of enzyme inhibiting compounds such as polyphenols [52].

The hindrance to attaining optimal use of cassava can best be achieved when cyanide-free strains are obtained from breeding programmes because they do not occur naturally [23]. Cyanide-free strains would make cassava reliably safe, more acceptable and marketable and reduce cyanide effluent from cassava processing plants [53]. Genetic engineering, using antisense technology, has been used to block the synthesis of linamarin, resulting in cyanide-free cassava. Dramatically reduced linamarin content in leaves and roots of wild-types has also been achieved by genetic manipulation [53-55].

The downside to this development, however, is the likelihood of having reduced plant yield as a result of stalling the synthesis of linamarin [56]. The resulting transgenic plant could not produce roots because of a lack of ammonia, which is produced by the roots using linamarin as its source. Obstructing the synthesis of linamarin also leaves the plant vulnerable to animal and insect attack since linamarin is used in a defensive mechanism [57]. Besides these technical and research issues, controversy and skepticism surrounding genetically modified organisms [58] may pose a challenge to the introduction and use of transgenic “strains” in part of the world. Genetic transformation and molecular biology techniques have not made any commercially remarkable impact even though they present great potential. Conventional methods of breeding, which involves selection and crossing varieties to yield desirable traits, have also been applied in a bid to reduce the cyanogen content in cassava. Previous studies by Iglesias *et al.* [59] showed reduced cyanogen content in some clones compared to their parental variety. The low vegetative multiplication rate and the fact that several factors affect the quality of planting material; however, complicates and makes this method quite difficult to implement [60].

Processing: Aside of genetic/breeding interventions embarked upon to obtain significantly reduced cyanogens content in cassava, biological detoxification methods such as enzyme and bacteria action and physical methods such as processing present suitable options to attaining a similar goal. These methods have resulted in tremendous and significant economic gains as far as the use of cassava is concerned. Detoxification essentially involves two separate treatments; first is one that enhances the contact between linamarase and its substrates (Cyanohydrins) followed by a second that volatilizes the HCN produced as a result of contact between the enzyme and its substrates. Processing largely promotes these conditions that are required for adequate detoxification. Cassava processing improves shelf-life, detoxifies the roots, facilitates transport and enhances consumer acceptability [61, 62].

The short coming of processing as a detoxification method, conversely, is that a lot of them result in loss of nutrients [63]. Enzymatic removal of cyanogens is commonly accomplished by treating samples with enzymes isolated from bacteria to breakdown cyanogenic compounds into acetone cyanohydrins, which decomposes 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 [64]. The latter principle has been exploited in the production of cassava starch [65]. The HCN produced is subsequently dissolves readily in water or is released into the air [63, 66].

The enzyme hydrolyses of the cyanogens is sensitive to changes in pH [67] with pH > 5 favoring the breakdown. Certain species of *Bacillus*, *Pseudomonas* and Klebsiella *oxytoca* have been reported to utilize cyanide as the only source of nitrogen under aerobic and anaerobic conditions thus breaking it down into non-toxic compounds [68]. *Bacillus subtilis* KM05 isolated from cassava peels has been used to detoxify cassava flour [63] by degrading linamarin into HCN and subsequently releasing ammonia. In another study by Nwokoro and Anya [69] cassava flour samples treated with linamarinase enzyme isolated from *L. delbrueckii* resulted in an 89.5% reduction in cyanide content.

Fermentation: Fermentation as a method of processing primarily enhances nutritional properties through biosynthesis of vitamins, essential amino acids and proteins, by improving protein quality and fiber digestibility as well as the enhancement of micronutrient bioavailability and degradation of anti-nutritional factors [70, 71] Fermentation of cassava, both aerobic and anaerobic, favors the hydrolysis of linamarin into HCN. Even though details of the mechanism involved are unclear [72] fermentation softens the cells of the roots and favours contact of the enzymes with its substrate. In the case of submerged fermentation, this process synergises with leaching of cyanogen to detoxify the cassava roots [73].

Three major types of fermentation are widely practiced in different parts of Africa; these are the grated root fermentation, mould fermentation of roots in heaps and fermentation of roots under water [61]. Fermentation of cassava roots is largely acidic (pH 3.8) while that for leaves is alkaline (pH 8.5) with lactic acid bacteria dominating the microbiota [74]. Some lactic acid bacteria and yeast possess linamarase activity and are recognized for significantly contributing to cyanogenic glycoside breakdown during fermentation of cassava [75].

These microorganisms are capable of utilizing the cyanogens and their degradation products [76] thereby ridding their substrate of these noxious substances and rendering the substrate safe. Previous reports have shown a remarkable reduction in cyanogenic potential of cassava following fermentation. More than 50 % and 35 % reduction in cyanogen levels has previously been achieved in the production of gari and fermented cassava flour respectively [77, 78] have also reported up to 41% reduction in cyanide levels during fermentation. Other researchers have also reported varying levels of decline in cyanogen potential after fermentation [79]. Indeed reduction in cyanide level in all cases depends on the initial cyanide levels of the raw material.

Soaking: Soaking cassava roots usually precedes fermentation, cooking or drying. Retting, followed by sun drying is exploited as a method of processing cassava roots in some parts of Africa. This technique of long soaking cassava roots in stagnant or slow running ponds and causes the breakdown of tissues and extraction of the starchy mass [80]. The water softens the cells of the cassava roots, provides a larger medium for fermentation and facilitates leaching of cyanogenic glycosides. The method removes a substantial amount of free cyanide but has little effect on bound cyanide. Soaking peeled or unpeeled cassava roots is practiced in the northern and central regions of Malawi [62] to produce 'waluwa' and 'kanyakaska' which are dried and pounded into flour and used to prepare a local delicacy called 'kodowole'. The cassava roots come out of the process having lost between 31.0% and 49.9% (For unpeeled and peeled roots respectively) of their cyanogenic potential. Other studies have resulted in remarkably significant reduction in cyanogenic glycosides after soaking [81].

Cooking: Boiling cassava roots, which is often for direct consumption with accompaniments such as soups and stews, is commonplace in most areas where cassava is produced for culinary purposes. Cooking is processing cassava roots by this method is preceded by peeling, cutting into11 chunks/dicing and washing. Disruption of cell membrane during cooking largely occurs between 60 and 70°C and not long after that linamarase is destroyed, making contact with its substrate inadequate for thorough detoxification. This causes a possible retention of cyanogenic glycoside levels [82]. Cyanohydrins from aldehydes, may also exist even after cooking because they are thermo-stable [50]. As a result, boiling is often criticized and an ineffective standalone method of detoxifying cassava roots and hence is preferred as a method of processing sweet cassava, although the heat favors rapid evaporation of HCN produced [83].

Indeed, the extent of reduction of cyanogenic glycosides has been related to the cooking time [82, 84] have reported cooking to reduce cyanogen potential by 50 -70% in Southern Asia [85]. Introduced a soaking and squeezing stage prior to cooking and achieved a remarkable reduction in cyanogenic potential of up to 70%. Boiling/cooking has also been applied to process cassava leaves and resulted in 75 % reduction [84] and in some cases more than 90% reduction in cyanide level [86].

Roasting Drying: Cassava roots have been processed in to a lot of dried products. Drying is widely accepted as an efficient processing method for cassava roots as it results in products that are shelf-stable with relatively reduced cyanide content. In as much as advanced systems of drying exist, sun drying is the most adopted method in cassava processing regions of Africa and as such sun-dried cassava products are the most common [61]. Dried cassava pieces can be processed further into other preferred forms. Drying or roasting cassava is usually preceded by peeling, chipping, chunking or grating before spreading out in the sun to dry. Detoxification is achieved by the drying mechanism in itself does not play any significant role in the detoxification process but the tissue disruption that precedes drying. The efficiency of cyanide removal during drying is dependent on moisture content of the roots, rate of moisture loss (Which relates to drying conditions) and the extent of tissue disruption [52]. The influence of moisture content on detoxification is crucial, as glucoside degradation has been observed to stop between 13% and 18% moisture. This is because diffusion of linamarin during drying continually decreases and at a point where bulk water for transport is lacking, it becomes immobilized thus preventing its interaction with linamarase in the drying medium [52, 87]. Extending the period of drying with higher moisture levels have been observed to result in enhanced linamarin breakdown, thus explaining the fact that fast drying rates result in lower detoxification while slower rates result in higher cyanogen removal [52]. Cyanohydrin levels remain high in the product during drying because of the enzyme hydrolysis that takes place, especially when root pieces are humid. Their levels could be reduced further by thorough drying well below 12 or 13% moisture. HCN levels conversely remain low during drying because it volatilizes as a result of its exposure to heat [87].

CONCLUSION AND RECOMMENDATIONS

Phytochemical and pharmacological investigations studied out in the plant *Manihot esculenta* in various literature sources reveal its multidisciplinary usage. It is very essential to have a proper documentation of medicinal plants and to know their potential for the improvement of health and hygiene through an eco-friendly system. *Manihot esculenta* Crantz, most popularly known as cassava is one of the most forgiving and adaptable plants. It is not so commonly used in herbal medicine, but indigenous people do employ it for various purposes. Because of some of its potentially toxic components which are removed by processing, sometimes it is considered as non-edible and toxic in various parts of the world but, it is definitely one of the most useful medicinal plants. Therefore, based on the above conclusion the following recommendations are forwarded: further pharmacological experiments should be performed in the plant to extend to the next level of clinical trial to generate novel drugs. Processing cassava into ready-to-eat products is necessary to remove cyanogens and other anti-nutrients. In addition to genetically engineering and traditionally breeding cassava to contain higher amounts of macronutrients, it is necessary to process cassava to reduce toxic cyanide and improve protein content and energy density. Continued efforts to improve its nutritional value are important because cassava is staple food for many people in developing countries.

REFERENCES

1. Heidari, R.M., M.E. Azad and M. Mehrabani, 2006. Evaluation of the analgesic effect of *Echium amoenum*, Fisch and C.A, May, Extract in mice; possible mechanism involved, J. Ethnopharmacol., 103: 345-349.

2. Kupeli, E, I.I. Tatli, S.Z. Akedemir and E. Yesilada, 2007a. Estimation of antinociceptive and antinfmmatory activity on *Geranium protense* subsp. Finitimum and its phenolic coumpounds, J. Ethnopharmacol., 114: 234-240.
3. Ojewole, O.A.J., 2004. Evaluation of the analgesic ant inflammatory and antidiabatic properties of Sclerocarya *birrea* (A.Rich.) Hochst. Stem bark aqueous extract in mice and rats. Phytother, Res., 18: 601-608.
4. Gedif, M. and H.J. Hahn, 2003. The use of medicinal plants in self-care in rural central Ethiopia, J. Ethnopharmacol., 87: 155-161.
5. Giday, M., Z. Asfaw and Z. Woldu, 2009. Medicinal plants of the meinit ethnic groups of Ethiopia: An ethno botanical study, J. Ethnopharmacol., 124: 513-521.
6. Alves, A.A.C., 2002. Cassava botany and physiology. CABI Publishing, Wallingford, UK, pp: 67-89
7. Ani, A.I., I.J. Atangwho, M.A. Agiang and Y.E. Alozie, 2012. Biochemical effects of some traditional Nigerian diets in experimental diabetic rat models. International Journal of Biochemistry Research, 2(2): 70-77.
8. Afolabi, L., O.O. Adeyemi and O.K. Yemitan, 2008. Cassava leaves have anti-inflammatory and analgesic principles, which justify its use in traditional African medicine. J. Ethnopharmacol., 119: 6-11.
9. Bahekar, S. and R. Kale, 2013. Psychopharmacological aspects of *Manihot esculenta* crantz (Cassava)-a review. Mintage Journal of Pharmaceutical and Medical Sciences.
10. Wobeto, C., A.D. Corrêa, C.M.P. De Abreu, C.D. Dos Santos and J.R. De Abreu, 2006. Nutrients in the cassava (*Manihot esculenta*, Crantz) leaf meal at three ages of the plant. Cienc Technol. Aliment, 26: 865-869.
11. Jayasri, P., D. Narendra, Naik and A. Elumalai, 2011. Evaluation of anthelmintic activity of *Manihot esculenta* leaves. Int. J. Curr. Pharm. Res., 3: 115-116.
12. Trinidad, P.T., S.S. Rosario, C.M. Aida, S.B. Melissa, P.D.L. Marco and F.A. Theressa, 2013. Sweet Potato and Cassava Can Modify Cholesterol Profile in Humans with Moderately Raised Serum Cholesterol Levels. Food and Nutrition Sciences, 4: 491-495
13. Dorota, L., Z. Rafał, G. Halina and S. Marek, 2014. Gluten Free Bread in a Diet of Celiacs. International Journal of Celiac Disease, 2(1): 11-16.
14. Charles, A.L., Y.H. Chang, W.C. Ko, K. Sriroth and T.C. Huang, 2004. Some physical and chemical properties of starch isolates of cassava genotypes. Starch/Starke, 56: 413-418.
15. Anbuselvi, S. and T. Balamurugan, 2014. Phytochemical and antinutrient constituents of cassava and sweet potato. World Journal of Pharmacy and Pharmaceutical Sciences, 3: 1440-1449.
16. Abeygunasekera, A.M. and K.H. Palliyaguruge, 2013. Does cassava help to control prostate cancer? A case report. Journal of Pharmaceutical Technology & Drug Research, pp: 2. doi: 10.7243/2050-120X-2-3
17. Abo-Salem, O.M., R.H. El-Edel, G.E.I. Harisa, N. El-Halawany and M.M. Ghonaim, 2009. Experimental diabetic nephropathy can be prevented by propolis: Effect on metabolic disturbances and renal oxidative parameters. Pakistan J. Pharm. Sci., 22: 205-210.
18. Okigbo, B.N., 1980. Nutritional implications of projects giving high priority to the production of staples of low nutritive quality. In the case for cassava (*Manihot esculenta*, Crantz) in the humid tropics of West Africa. Food Nutr Bull, 2: 1-10.
19. Gil, J.L. and A.J.A. Buitrago, 2002. La yuca en la alimentacion animal. In: Ospina B, Ceballos H, editors. La yuca en el tercer milenio: sistemas modernos de producci´on, procesamiento, utilizaci ´on y comercializaci ´on. Cali, Colombia: Centro Internacional de Agricultura Tropical., pp:: 527-569.
20. Rawel, H.M. and J. Kroll, 2003. Die Bedeutung von Cassava (*Manihot esculenta*, Crantz) als Hauptnahrungsmittel in tropischen L¨andern. Deutsche Lebensmittel-Rundschau, 99: 102-110.
21. Tewe, O.O. and N. Lutaladio, 2004. Cassava for livestock feed in sub-Saharan Africa. Rome, Italy: FAO.
22. Hudson, B.J.F. and A.O. Ogunsua, 1974. Lipids of cassava tubers (*Manihot esculenta*, Crantz). J. Sci. Food Agric., 25: 1503-1508.
23. Bradbury, J.H. and W.D. Holloway, 1988. Cassava, *M. esculenta*. Chemistry of tropical root crops: significance for nutrition and agriculture in the pacific. Australian center for international agricultural research, Monograph 6, Canberra, Australia, pp: 76-104.
24. Montagnac, J.A., C.R. Davis and S.A. Tanumihardjo, 2009. Processing techniques to reduce toxicity and antinutrients of cassava for use as a staple food. Comp Rev Food Sci Food Safety, 8: 17-27.

25. El-Sharkawy, M.A., 2003. Casssava biology and physiology. Plant Mol. Biol., 53: 621-641.
26. Adewusi, S.R.A. and J.H. Bradbury, 1993. Carotenoid in cassava: comparison of open column and HPLC methods of analysis. J. Sci. Food Agric., 62: 375-383.
27. Eggum, R.O., 1970. The protein quality of cassava leaves. Br J. Nutr., 24: 761-768.
28. Jacquot, R., 1957. Les facteurs d'efficacit´e alimentaire. In: Nutrition et alimentation tropicales. Tome 1, AO editions. Rome, Italy: FAO.
29. Chavez, A.L., J.M. Bedoya, T. Sanchez, C. Iglesias, H. Ceballos and W. Roca, 2000. Iron, carotene and ascorbic acid in cassava roots and leaves. Food Nutr. Bull., 21: 410-413.
30. Madruga, M.S. and F.S. Camara, 2000. The chemical composition of "Multimistura" as a food supplement. Food Chemistry, 68: 41-44.
31. Montagnac, J.A., R.D. Christopher and S.A. Tanumihardjo, 2009. Nutritional Value of Cassava for Use as a Staple Food and Recent Advances for Improvement. Comprehensive Reviews in Food Science and Food Safety, 8: 181-194.
32. Rock, C.L., 2007. Primary dietary prevention: is the fiber story over? Recent Results Cancer Res., 174: 171-177.
33. Wobeto, C., A.D. Corrêa, C.M.P. De Abreu, C.D. Dos Santos and H.V. Pereira, 2007. Anti-nutrients in the cassava (*Manihot esculenta* Crantz) leaf powder at three ages of the plant. Cienc Technol. Aliment, 27: 108-112.
34. Ogbadoyi, E.O., A.H. Makun, O.R. Bamigbade, O.A. Oyewale and J.A. Oladiran, 2006. The effect of processing and preservation methods on the oxalate levels of some Nigeria leafy vegetables. Biokemistri., 18: 121-125.
35. Achidi, A.U., O.A. Ajayi, B. Maziya-Dixon and M. Bokanga, 2008. The effect of processing on the nutrient content of cassava leaves J. Food. Process. Preserv., 32: 486-502.
36. Dini, I., G.C. Tenore and A. Dini, 2009. Saponins in *Ipomoea batatas* tubers: Isolation, characterization, quantification and antioxidant properties. Food Chem., 113: 411-419.
37. Rhou, J.R. and J.V. Erdman, 1995. Phytic acid in Health and Disease. Critical Reviews in Food Science and Nutrition, 35: 495-508.
38. Fasuyi, A.O., 2005. Nutrient composition and processing effects on cassava leaf (*Manihot esculenta*, Crantz) antinutrients. Pakistan Journal of Nutrition, 4: 37-42.
39. Beecher, G.R., 2003. Overview of dietary flavonoids; nomenclature occurrence and nitrate. Journal of Nutrition, 133(10): 32485-32545.
40. Greenwell, I., 2000. Antioxidant Power. In: Life Extension Magazine March Life Extension Foundation, Boston.
41. Haque, M.R. and J.H. Bradbury, 2004. Total cyanide determination of plants and foods using the picrate and acid hydrolysis methods. Food Chemistry, 77: 107-114.
42. Nhassico, D., H. Muquingue, J. Cliff, A. Cumbana and J.H. Bradbury, 2008. Rising African cassava cyanide intake and control measures. Journal of Science. Food and Agriculture, 88: 2043-2049.
43. Ermans, A.M., N.M. Mbulamoko, F. Delange and R. Ahluwalia, 1980. Role of cassava in the Etiology of Endemic Goitre and Cretenism International Research Centre. Ottawa.
44. Gomez, G. and M. Valdivieso, 1985. Cassava foliage: chemical composition, cyanide content and effect of drying on cyanide elimination. Journal of Science Food and Agriculture Chichester, 36: 433-441.
45. Massey, L.K., 2007. Food oxalate: Factors affecting measurement, biological variation and bioavailability. Journal of American Dietetic Association, 107: 1191-1194.
46. Mohri, T., 1993. Nitrates and Nitrites. In: Encyclopaedia of Food Science, Food Technology and Nutrition. Vol. 5. (Eds.) Macrae, R; R. K. Robinson and M. J. Sadler. Academic Press, London, pp: 3240-3244.
47. Gupta, P., K. Dhawan, S.P. Malhotra and R. Singh, 2002. Purification and characterization of trypsin inhibitor from seeds of faba bean (*Vicia faba* L). Acta Physiology. Plantarum, 22: 433-438.
48. Ricardo, B., 1993. Amaranth. In: Encyclopaedia of Food Science Technology and Nutrition. Academic press, London, 1: 135-140.
49. Prasad, S. and A.A. Chetty, 2008. Nitrate-N determination in leafy vegetables: Study of the effects of cooking and freezing. Food Chemistry, 106: 772-780.

50. Onabolu, A.O., O.S.A. Oluwole, H. Rosling and M. Bokanga, 2002. Processing factors affecting the level of residual cyanohydrins in Gari. Journal of the Science of Food and Agriculture, 82: 966-969.
51. Iwastuki, N., M. Kojima, E.S. Data and C.D.V. Villegas-Godoy, 1984. Changes in cyanide content and linamarase activity in cassava roots after harvest. In: Uritani, I. and Reyes, E.D. (eds), Tropical root crops-postharvest physiology and processing. Japan Scientific press, Tokyo, pp: 151-161.
52. Essers, A.J.A., R.M. Van Der Grift and A.G.J. Voragen, 1996. Cyanogen removal from cassava roots during sun-drying. Food Chemistry, 55: 319-325.
53. Siritunga, D. and R.T. Sayre, 2003. Generation of cyanogen - free transgenic cassava. Planta, 217: 367-373.
54. Andersen, M.D., P.K. Busk, I. Svendsen and B.L. Moller, 2000. Cytochromes from cassava (*Manihot esculenta* Crantz) catalyzing the first steps in the biosysnthesis of the cyanogenic glycosides linamarin and lotaustralin: cloning, functional expression in Pichiapastoris and substrate specificity of the isolated recombinant enzymes. Journal of Biology and Chemistry, 275: 1966-1975.
55. Siritunga, D. and Sayre R.T., 2004. Engineering cyanogen synthesis and turnover in cassava (*Manihot esculenta*). Plant Molecular Biology, 56: 661-669.
56. Taylor, N., P. Chavarriaga, K. Raemakers, D. Siritunga and P. Zhang, 2004. Development and application of transgenic technologies in cassava. Plant Molecular Biology, 56: 671-688.
57. Vetter, J., 2000. Plant cyanogenic glycosides. Toxicon, 38: 11.
58. Falkner, R., 2004. The first meeting of the parties to the Cartagena protocol on bio safety. Environmental Politics, 13: 635-641.
59. Iglesias, C.A., T. Sanchez and H.H. Yeoh, 2002. Cyanogens and Linamarase activities in storage roots of cassava plants from breeding program. Journal of Food Composition and Analysis, 15: 379-387.
60. Ceballos, H., E. Okogbenin, J.C. Perez, L.A.B. Lopez-Valle and D. Dubouck, 2010. Cassava. In: Bradshaw, J.E. (ed). Roots and Tuber Crops, Springer Science and Business media, London, pp: 53-96.
61. Westby, A., 2002. Cassava Utilization, storage and small-scale processing. In: Hillocks, R.J., thresh, J.M. Bellotti, A., (eds) Cassava: Biology, production and utilization. CAB Publishing International, pp: 281-300.
62. Nyirenda, D.B., L. Chiwona-Karltun, M. Chitundu, S. Haggblade and L. Brimer, 2011. Chemical safety of cassava products in regions adopting cassava production and processing – Experience form Southern Africa. Food and Chemical Toxicology, 49: 607-612.
63. Murugan, K., K. Yashotha-Sekar and S. Al-Sohaibani, 2012. Detoxification of cyanides in cassava flour by linamarase of *Bacillus subtilis* KM05 isolated from cassava peel. African Journal of Biotechnology, 11: 7232-7237.
64. Yeoh, H.H. and F. Sun, 2001.Assessing cyanogen content in cassava-based food using the enzyme-dipstick method. Food and Chemical Toxicology, 39: 649-653.
65. Sornyotha, S., K.L. Kyu and K. Ratanakhanokchai, 2010. An efficient treatment for detoxification process of cassava starch by plant cell wall-degrading enzymes. Journal of Biosciences and Bioengineering, 109: 9-14.
66. Rolle, R.S., 1998. Enzyme application for agro-processing in developing countries: an inventory of current and potential applications. World Journal of Microbiology and Biotechnology, 14: 611-619.
67. Cumbana, A., E. Mirione, J. Cliff and J.H. Bradbury, 2007. Reduction of cyanide content of cassava flour in Mozambique by the wetting method. Food Chemistry, 101: 849-897.
68. Kaewkannetra, P., T. Imai, F.J. Garcia-Garcia and T.Y. Chiu, 2009. Cyanide removal from cassava mill wastewater using *Azotobacter vinelandii* TISTR 1094 with mixed microorganisms in activated sludge treatment system. Journal of Hazardous Material, 172: 224-228.
69. Nwokoro, O. and F.O. Anya, 2011. Linamarinase enzyme from *Lactobacillus delbrueckii* NRRL B-763: Purification and some properties of a β-Glucosidase. Journal of Mexican Chemical Society, 55: 246-250.
70. Achinewhu, S.C., L.I. Barber and I.O. Ijeoma, 1998. Physicochemical properties and garification (Gari yield) of selected cassava cultivars in River States, Nigeria. Plant Food for Human Nutrition, 52: 133-140.
71. Motarjemi, Y., 2002. Impact of small scale fermentation technology on food safety in developing countries. International Journal of Food Microbiology, 75: 213-229.
72. Vasconcelos, A.T., D.R. Twiddy, A. Westby and P.J.A. Reilly, 1990. Detoxification of cassava during gari preparation. International Journal of Food Science and Technology, 25: 198-203.

73. Westby, A. and B.K. Choo, 1994. Cyanogen reduction during the lactic fermentation of cassava. Acta Horticulturae, 373: 209-215.
74. Oyewole, O.B. and S.L. Ogundele, 2001. Effect of length of fermentation on the functional characteristics of fermented cassava 'fufu'. The Journal of Food Technology in Africa, 6: 38-40.
75. Kimaryo, V.M., G.A. Massawe, N.A. Olasupo and W.H. Holzapfel, 2000. The use of a starter culture on the fermentation of cassava for the production of kivumde a traditional Tanzanian food product. International Journal of Food Microbiology, 56: 179-190.
76. Akindahunsi, A.A., G. Ohoh and A.A. Oshodi, 1999. Effect of fermenting cassava with *Rhizopus oryzae* on the chemical composition of its flour and gari. Rivista Italiana delle Sostanze Grasse, 76: 437-440.
77. Kemdirim, O.C., O.A. Chukwu and S.C. Achinewhu, 1995. Effect of traditional processing of cassava on the cyanide content of gari and cassava flour. Plant food for Human Nutrition, 48: 335-339.
78. Enidiok, S.E., L.E. Attah and C.A. Otuechere, 2008. Evaluation of moisture, total cyanide and fiber contents of Garri produced from cassava (*Manihot utilissima*) varieties obtained from Awassa in Southern Ethiopia. Pakistan Journal of Nutrition, 7: 625-629.
79. Djoulde, D.R., N.J.J. Essia and F.X. Etoa, 2007. Nutritive value, toxicological and hygienic quality of some cassava based products consumed in Cameroon. Pakistani Journal of Nutrition, 6: 404-408.
80. Ayernor, G.S., 1985. Effects of the retting of cassava on product yield and cyanide detoxification. Journal of Food Technology, 20: 89-96.
81. Ampe, F. and A. Brauman, 1995. Origin of enzymes involved in detoxification and root softening during cassava retting. World Journal of Microbiology and Biotechnology, 11: 178-182.
82. Jansz, E.R. and D.I. Uluwaduge, 1997. Biochemical aspects of cassava (*Manihot esculenta* crantz) with special emphasis on cyanogenic glucosides – A Review. Journal of the National. Science Council of Srilanka, 25: 1-24.
83. Bokanga, M., 1995. Biotechnology and cassava processing in Africa. Food Technology, 49: 86-90.
84. Hidayat, A., N. Zuraida and I Hanarida, 2002. The cyanogenic potential of roots and leaves of ninety nine cassava cultivars. Indonesian Journal of Agricultural Science, 3: 25-32.
85. Fukuba, H., O. Igarashi, C.M. Briones and E.M.T. Mendoza, 1982. Determination and detoxification of cyanide in cassava and cassava products. Philippians Journal of Crop Science, 7: 170-175.
86. Ngudi, D.D., Y.H. Kuo and F. Lambein, 2003. Cassava cyanogens and free amino acids in raw and cooked leaves. Food and Chemical Toxicology, 41: 1193-1197.
87. Mlingi, N.L.V., Z.A. Bainbridge, N.H. Poulter and H. Rosling, 1995. Critical stages in cyanogen removal during cassava processing in southern Tanzania. Food Chemistry, 53: 29-33.