academicJournals

Vol. 6(3), pp. 29-38, June, 2014
DOI 10.5897/JABSD2014.0224
ISSN 1996-0816
Article Number: CD4240F45805

http://www.academicjournals.org/JABSD

Journal of Agricultural Biotechnology and Sustainable Development

Review

Production, consumption and nutritional value of cassava (*Manihot esculenta,* Crantz) in Mozambique: An overview

Salvador E. M.[1], Steenkamp V.[2] and McCrindle C. M. E.[1]*

[1]School of Health Systems and Public Health, Faculty of Health Sciences, University of Pretoria, HW Snyman Building Private Bag X323, Pretoria 0001, South Africa.
[2]Department of Pharmacology, Faculty of Health Sciences, Basic Medical Sciences, University of Pretoria (BMS) building, Private Bag X323, Arcadia, 0007 Pretoria, South Africa.

Received 12 May, 2014; Accepted 17 June, 2014

Both soils and climate in Mozambique suit cassava cultivation and nine million tons fresh weight is produced annually, with a consumption of 85 kg per person per year. The roots are a staple carbohydrate and cooked leaves are served as a vegetable. Cassava is essential to food security, as it is a subsistence crop. Roots and leaves contain vitamin C and some minerals but are deficient in proteins and amino-acids. Although cassava is cultivated by about 63% of the population, cyanogenic glycosides and other anti-nutritional factors, threaten food safety. There are more than 100 varieties, but the more drought and insect resistant bitter types predominate. Traditional products made from cassava that rely on sun-drying, cooking or fermentation to reduce toxicity include "*rale*", "*xinguinha", "karakata"* "*mahewu*" and "*oteka*". Cassava flour has replaced up to 20% of wheat flour in bread, for economic reasons. An overview of the distribution, consumption patterns and nutritional value of cassava in Mozambique could contribute to knowledge, as much of the existing data has not been published. Food safety and nutritional value could be improved by commercializing the production of traditional products or fortifying the affordable staple carbohydrate. This could improve the health of vulnerable rural populations.

Key words: Cassava production, cassava consumption, food security, traditional foods, cyanogenic glycosides, Mozambique.

INTRODUCTION

Mozambique, one of the poorest countries in Africa (UNDP, 2010) is located in the south east of the continent. The country covers an area of about 799,380 km^2 which includes 36 million hectares of arable soil and a coastline of 2,740 km (FAO, 2011b). The climate in Mozambique is tropical and humid with two distinct seasons. Winter (April to September) is normally cold and dry, while the summer (October to March) period is warm and rainy. The annual ambient temperature is between 23 and 26°C for the coastal zones of southern and

*Corresponding author. E-mail: cheryl.mccrindle@up.ac.za; Tel +27827877823.

northern Mozambique with a mean annual rainfall of approximately 1200 mm (Hoguane, 2007).

The most recent census data was published in 2009 by the National Institute of Statistics (INE) following the last National Population Census, done in 2007. The population of Mozambique was recorded as 21 284 701, with more than 70% living in rural areas. Population density was 27 per km^2, growing at a rate of 1.7% per year. The gross birth ratio in the country was 42.2 per 1000 inhabitants, with an infant mortality of 94 deaths per 1000 live births and life expectancy of 49.4 years. About 80% of Mozambicans depended on agriculture for their livelihood and the agricultural sector remained the key for social and economic growth (INE, 2009).

Mozambique has been ranked 8th in the world and 5th among African countries with regards to cassava production (FAO, 2011a). It is an important staple food in Mozambique, second only to maize (Walker et al., 2006). Maize does not grow easily in certain regions of Mozambique (Tostao and Wade, 2005). The transportation of maize from high production areas to consumers in other areas is not cost effective (Nielson, 2009). Imported maize originates mainly from South Africa and it is significantly more expensive than cassava (Howard et al., 2003; Tschirley et al., 2006). Mozambique was involved in a protracted war which ended in 1992. This war impacted negatively on food production and bitter cassava was sometimes consumed without further processing, causing acute and chronic poisoning due to cyanogenic glycosides (Cliff, 1994). In the two decades since the war ended, efforts have been made to increase local crop production to reduce imports and improve foreign exchange (Mader, 2005; FAOSTAT, 2011b). Cassava is easily cultivated as a subsistence crop in Mozambique, with more than 90% being produced for human consumption (FAOSTAT, 2011b). Consumption has been estimated as 85kg per person per year (IOF, 2008/2009). Cassava is drought-tolerant and mature roots maintain their nutritional value for up to three years (Montagnac et al., 2009b; Gbadegesin et al., 2013). It is a multiple year crop and roots can be kept in the ground until needed, thus increasing food security (El-Sharkawy, 2004; Donovan et al., 2011; Gbadegesin et al., 2013). Cyanogenic glycosides and other anti-nutritional factors are a threat to human health that is well recognized in Mozambique (Ministry of Health Mozambique, 1984; Essers et al., 1992; Cliff, 1994; Cliff et al., 1997; Nhassico et al., 2008; Cliff et al., 2011). However, a less recognized threat is the poor nutrient quality, which because of the high level of consumption of this staple carbohydrate, threatens a large proportion of the population with malnutrition and poor quality of life.

Fermentation of cassava is known to reduce the toxicity of cyanogenic glycosides. It also results in higher levels of vitamins, especially the B group, and essential amino acids and improves digestibility of protein (Amoa-Awua and Frisvad, 1997; Oyewole, 2001; Boonnop et al., 2009). Traditional foods made from fermented cassava in Mozambique include *rale, karakata, mahewu, ottaca* and *oteka.* (Tivana et al., 2009; Donovan et al., 2011; Tivana, 2012; Hagglades et al., 2012; Salegua et al., 2012). This overview aims to consolidate knowledge on the production, consumption and nutritional value of cassava in Mozambique, with a view to stimulating research to improve food safety and nutrition, particularly in vulnerable rural populations.

Cassava production

Area cultivated and yield

The cropping season for cassava is described as flexible, because roots can be harvested between eight months and three years after planting (FAO/WFP, 2010). In 2011 the total cultivated area was estimated as 5 632 781 ha. The greater proportion of this was used by small scale farmers (96.4%). The remainder was cultivated by medium (2.3%) and larger scale (1.3%) farmers (INE, 2011). Approximately 2 425 240 ha (43%) of this total cultivated area was used for cassava production. Similar to other food crops in Mozambique, cassava is grown mainly (99.7%) by subsistence and small scale family farmers. Medium scale farmers use only 0.3% of the available land and large scale farmers only 0.01% (INE, 2011).

According to the Agriculture and Livestock Census 2009 to 2010, cassava is cultivated throughout the country. The three provinces with the highest production are Nampula Province, in the northern region (29.27%); Zambesia Province in the central region (26.76%); and Inhambane Province (8.80%) in the southern region (ine, 2011). The estimated production per region is shown in Figure 1. Cassava production increased between 2002 and 2008, when the average production was estimated as six million tons. It rose further to nine million tons in 2010 (FAOSTAT, 2011b). Overall, between 2005 and 2012, the yield of cassava in hectogram per hectare increased from 43.155 to 131.804 (Factfish, 2014). By 2012, the production of cassava had escalated to 10.05 million tons (Factfish, 2014).

Cassava varieties

Varieties (also called cultivars) are classified according to morphological traits as well as taste, cyanide content, average yield, disease performance and pubescence (MIC, 2007; Gbadegesin et al., 2013). More than 5,000 cassava cultivars are recognized globally (Best, 1993; Bokanga, 1994; Gade, 2003; IFAD/FAO, 2005) and 100 varieties have been documented in Mozambique (INIA/IITA/SARRNET, 2002). Varieties grown in Mozambique are known to vary according to region; the

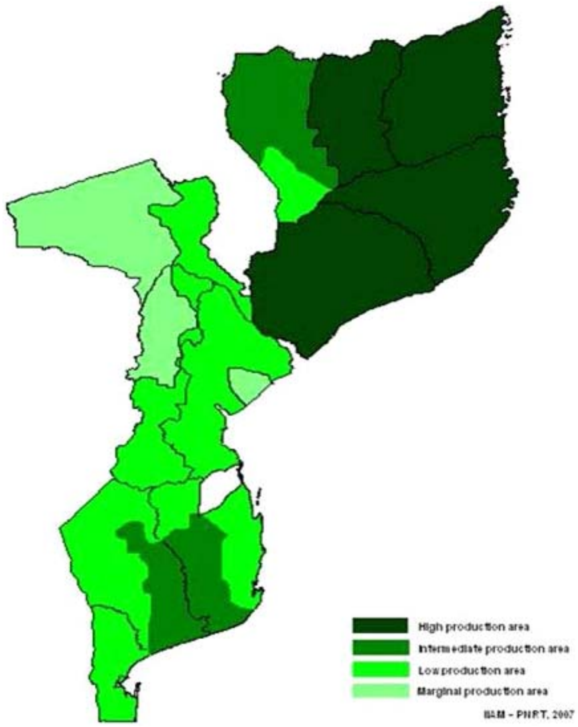

Figure 1. Cassava production area in Mozambique; Source: IIAM/PNRT, (2007).

Munhaça variety being most common in the Southern Region; *Inciricano* and *Bedo* in the Central Region and *Nikwaha*, *Tomo* and *Cororo* varieties, in the Northern Region (MIC, 2007). Consumer preferences influence the variety consumed and are based on the color of the plant, sharpness of the leaf lobe and the color of the root peel (MIC, 2007; Gbadegesin et al., 2013).

There are two major types of cassava: sweet and bitter (Chiwona-Karltun et al., 2004; Mkumbira et al., 2003; MIC, 2007). The flavor is influenced by the amount of cyanogenic glycoside present (McKey and Beckerman, 1993; Chiwona-Karltun et al., 2004). In the roots, cyanogenic glycosides range from 10 to 500 mg cyanide equivalent/kg dry matter (Arguedas, 1982; Siritunga and Sayre, 2003). Cassava leaves contain between 53 to 1,300 mg cyanide equivalents/kg of dry weight (Siritunga and Sayre, 2003; Wobeto et al., 2007). Bitter varieties contain more than 100 mg/kg fresh weight of hydrogen cyanide (Dufour, 1988; McKey et al., 2010).

These bitter varieties comprise more than 90% of production as they have a higher yield, are tolerant to pests and diseases and the potential for storage in the soil is greater than 12 months (Chiwona-Karltun et al, 1998; MIC/FAO/EC, 2004; Mader, 2005). It is essential to process bitter cassava to remove cyanogenic glycosides before consumption (Zvauya et al., 2002; Cardoso et al., 2005; Bradbury, 2006; Cumbana et al., 2007). Sweet varieties contain less than 100 mg/kg fresh weight of hydrogen cyanide, so are consumed fresh, sometimes even raw (Dufour, 1988; Mowat, 1989; Cardoso et al., 2005; Bradbury 2006; Cumbana et al., 2007; Donovan et al 2011).

Climate and production areas

In Mozambique there are ten agro ecological zones (Figure 2). The classification of these zones is based on climate, vegetation, altitude, soil and farming systems. It can be seen from Table 1 that the majority of cassava is grown in the poor and marginal zones of Mozambique (INIA, 1994).

Cassava consumption

The form in which cassava is consumed varies in the different regions of the country. In the Northern Region cassava flour (71% of production) is mainly boiled with water to make porridge. In this region the consumption of dried cassava accounts for 21% and fresh cassava for 8%, while the consumption of roasted cassava (*rale*) is not common (IOF, 2008 to 2009; Donovan et al, 2011; Hagglades et al., 2012).

In the Central Region, cassava is mainly consumed fresh (60%), cooked in different kinds of traditional

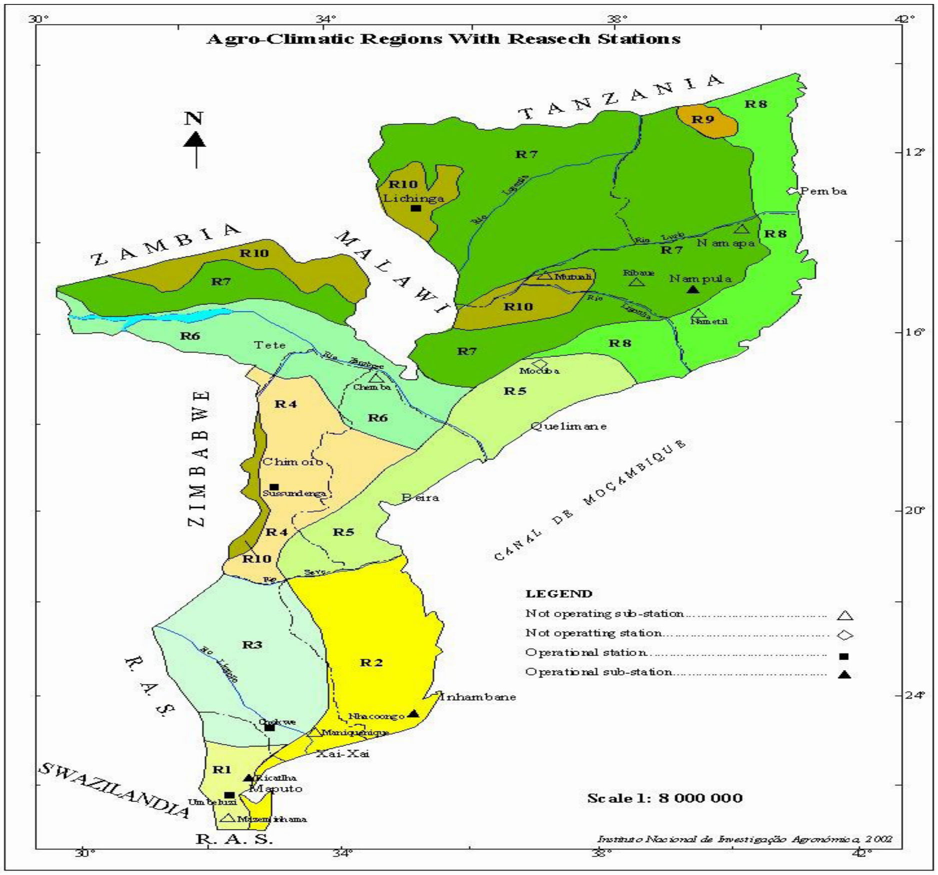

Figure 2. Agro-ecological zones of Mozambique (R1-R10); Source: INIA, (1994).

dishes. The consumption of flour and dried cassava accounts for only 31 and 9% of consumption respectively, with *rale* consumption being uncommon (Tivana et al., 2009; Donovan et al., 2011; Hagglades et al., 2012). Cassava consumption in the Southern Region is mainly in the fresh form (74%), followed by *rale* (19%). The flour and dried forms constitute 2 and 5%, respectively (IOF, 2008/09; Donovan et al, 2011; Hagglades et al., 2012).

Bitter cassava varieties must be processed to reduce or eliminate cyanogenic content (Chiwona-Karltun et al., 2000). The roots are boiled, roasted, sun dried, heap fermented or grated. Sweet varieties are mainly consumed fresh (Zvauya et al., 2002; Cardoso et al., 2005; Bradbury, 2006; Cumbana et al., 2007). Products that can be made from either sweet or bitter cassava roots include bread, biscuits, cakes and beverages.

Cooked cassava

Approximately 10% of total consumption is cooked cassava, from mainly sweet varieties (Donovan et al., 2011). Due to the high temperature achieved during boiling, the enzyme linamarase can inactivate cyanide in bitter cassava roots (Nambisan and Sundareson, 1985, 1994). Traditionally, in Southern Mozambique, cassava is cooked with other vegetables and peanuts, in a dish known as *xinguinha*. Boiled cassava root, either sweet or bitter, is traditionally served with a green salad and tea. Cassava leaves are generally cooked to make a dark green vegetable that looks like spinach and can be flavored with different spices.

Cassava flour

About 67% of cassava root harvested, is processed into flour (IOF, 2008 to 2009). The roots are first peeled and chipped or fermented, then sun dried before milling at community flour-mills. Direct sun-drying is commonly used for preparation of sweet varieties; whereas fermenting followed by sun drying is used in the preparation of bitter varieties (Zvauya et al., 2002; Tivana et al., 2007; Tivana et al., 2009). The inclusion of the fermentation process reduces or removes cyanogenic glycosides, as well as anti-nutritional factors, such as phytates and polyphenols (Montagnac et al., 2009a). In the Northern Region, cassava flour is mainly used to

Table 1. Agro ecological zones for cassava growth with their agro-climatic conditions.

Zone	Altitude (m)	Precipitation (mm)	Temperature (°C)	Humidity index	Predominant soils
R2	0 - 200	800 - 1000	24 - 26	Humid semi-arid, with some sub-humid spots in the littoral	Arenosol, fluvisols and manangas
R5	0 - 200	1000 - 1400	24 - 26	Humid semi-arid	Fluvisols and arenosols
R7	200 - 500	1000 - 1200	20 - 25	Humid semi-arid, with sub-humid	Feralsols, luvisols, acrisols
R8	0 - 200	800 - 1200	24 - 26	Humid semi-arid, with spots sub-humid and an extensive of spots of dry semi-arid	Lixisols, leptosols, arenosols

Source: INIA, (1994).

make a stiff porridge known as *karakata* (Tivana et al., 2007; Tivana, 20012), which is served with vegetables, fish or meat. Cassava flour is used to bake bread and has replaced between 10 and 20% of wheat flour in Mozambique (Salegua et al., 2012). It is also used to bake cakes, as it is more affordable and available than wheat.

Rale (roasted cassava roots)

Rale is the traditional name for roasted fermented cassava root and it is a ready to eat food. It can be consumed as a snack with tea, or used as a basic staple food with cooked vegetables or meat. The vegetables or meat are often curried. Although, *rale* only accounts for approximately 1% of overall consumption of cassava products, (IOF, 2008 to 2009) it is almost 20% in the Southern Region (Donavan et al., 2011).

Cassava beverages

Oteka and *impala* are alcoholic cassava beverages. These beverages are prepared by cooking cassava flour with water to make a thin starch porridge, which is then mixed with sorghum and malt. This form of cassava is consumed when there is a family celebration, or as a reward at the end of a working day (Donavan et al., 2011; Hagglades et al., 2012). *Mahewu* is a non-alcoholic fermented beverage made from sweet and bitter cassava. The preparation of cassava *mahewu* in Mozambique has not been documented. It was observed that, in Mozambique, fresh cassava root or flour was cooked to form a porridge, which was cooled and then fermented. Traditionally, bread, sorghum, millet malt or wheat flour is fermented to make a starter culture. Fermentation takes 24 to 36 hours at room temperature. Generally sugar was seen to be added to sweeten the *mahewu* before it was consumed.

Nutritional value of cassava

The nutritional content of cassava depends on the specific plant part (root or leaves), geographic location, variety, age of the plant and environmental conditions (FAOSTAT, 2011a). The cassava root is composed of carbohydrates and is therefore mainly a source of energy. The starch content varies between 32 to 35% of the mass of fresh roots and 80 and 90% of the mass of dried roots (Montagnac et al., 2009b). Amylopectin comprises 83% of the carbohydrate content of cassava roots while amylose comprises 17% (Rawel and Kroll, 2003). The amount of sucrose, glucose, fructose and maltose is usually low (Tewe, 2004), however, in sweet varieties more than 17% of the root content is sucrose (Okigbo, 1980; Charles et al., 2005). Fiber content differs according to the variety and stage of development of the root. In fresh roots it is less than 1.7%, while it comprises4% of cassava flour (Gil and Buitrago, 2002). Lipid content varies between 0.1 and 0.3% of the fresh mass of cassava roots and is present as nonpolar (45%) or glycolipids (52%) (Hudson and Ogunsua, 1974).

The protein content is trivial, between 1 and 3% of dry matter (Buitrago, 1990) and about 1.5 mg/100 g of fresh mass (Bradbury and Holloway, 1988). Essential amino acids are present in low quantities, with the exception of arginine, glutamic acid and aspartic acid (Gil and Buitrago, 2002). The mineral content of the roots varies (Table 2). According to Burns at al. (2012) in a study in Mozambique (Maputo and Nampula Provinces) iron content of cassava roots, varied from 8 to 24 mg/kg whereas zinc was between 3 to 140 pm (Burns et al., 2012). The vitamin content of the roots is low, except for vitamin C, which is found at relatively high levels of between 15 to 45 mg/100g per edible portion (Okigbo, 1980; Gil and Buitrago, 2002; Charles et al., 2004). The content

Table 2. Proximate nutrient composition of cassava roots and leaves.

Variable	Unit	Raw cassava[a]	Cassava roots[b,c,d]	Cassava leaves[b,c]
Proximate composition 100 (g)				
Food energy	kcal	160	110 - 149	91
Food energy	kj	667	526 - 611	209 - 251
Moisture	g	59.68	45.9 - 85.3	64.8 - 88.6
Dry weight	g	40.32	29.8 - 39.3	19 - 28.3
Protein	g	1.36	0.3 - 3.5	1.0 - 10.0
Lipid	g	0.28	0.03 - 0.5	0.2 - 2.9
Total carbohydrate	g	39.06	25.3 - 35.7	7 - 18.3
Dietary fiber	g	1.8	0.1 - 3.7	0.5 - 10.0
Ash	g	0.62	0.4 - 1.7	0.7 - 4.5
Vitamins				
Thiamin	mg	0.087	0.03 - 0.28	0.06 - 0.31
Riboflavin	mg	0.048	0.03 - 0.06	0.021 - 0.74
Niacin	mg	0.854	0.6 - 1.09	1.3 - 2.8
Ascorbic acid	mg	20.6	14.9 - 50	60 - 370
Vitamin A	µg	-	5.0 - 35.0	8300 - 11800[e]
Minerals				
Calcium	mg	16	19 - 176	34 - 708
Total phosphorus	mg	27	6 - 152	27 - 211
Ca/P		0.6	1.6 – 5.48	2.5
Iron	mg	0.27	0.3 - 14.0	0.4 - 8.3
Potassium	%	-	0.25 - 0.72	0.35 - 1.23
Magnesium	%	-	0.03 - 0.08	0.12 - 0.42
Copper	ppm	-	2.00 - 6.00	3.00 - 12.0
Zinc	ppm	-	14.00 - 41.00	71.00 - 249.0
Sodium	ppm	-	76.00 - 213.00	51.0 - 177.0
Manganese	ppm	-	3.00 - 10.00	72.0 - 252.0

Source: [a]Values were obtained from the USDA Natl. Nutrient database for standard references (http://www.nal.usda.gov/fnic/foodcomp/search/). Nutrient values and weights are for the edible portion; [b]Bradbury and Holloway (1988); [c]Woot-Tsuen et al., (1968); [d]Favier (1977); [e]Lancaster et al., (1982).

of B vitamins of cassava roots is also found to be trivial (Gil and Buitrago, 2002).

The nutrient density of cassava leaves differs in quantity and quality according to cassava variety, stage of development of the shrub and the relative size of the leaves and stem (Gil and Buitrago, 2002). As can be seen from Table 2, cassava leaves contain a higher amount of protein, essential amino acids, vitamins B_1, B_2, and C and carotenoids than roots (Adewusi and Bradbury, 1993; Okigbo 1980; West at al., 1988) and the starch content varies from 7 to 18 g/100g (Gil and Buitrago, 2002). They also contain more minerals such as calcium, iron, manganese, and magnesium and zinc (Webeto at al., 2006). In Mozambique (Maputo and Nampula Provinces) iron content in cassava leaves ranged from 284 to 93 mg/kg and the zinc concentrations varies between 47,8 and 27,0 mg/kg (Burns et al., 2012).

Anti-nutritional factors in cassava

Cassava contains anti-nutritional compounds that affect the digestibility and absorption of nutrients. Processing techniques are used to counteract or denature anti-nutritional factors and increase nutritional value of the leaves and roots (Montagnac et al., 2009b). These anti-nutritional factors include phytates, polyphenols, oxalates, nitrates and saponins. The quantity depends on the variety of cassava and plant maturity (Nambisan and Sundareson, 1994; Montagnac et al., 2009a; Bandna et al., 2012 - 2013).

Phytate content of roots is about 624 mg/100 g in the roots (Marfo et al., 1990). It interferes with the uptake and utilisation of minerals such as calcium, iron, molybdenum and zinc in consumers (Hambidge at al., 2008). Phytate has also been reported to interfere with the enzymatic process of protein digestion in the gut (Singh and Krikorian, 1982).

Polyphenols or tannins, mainly found in cassava leaves, range from 2.1 to 120 mg/100g dry weight (Wobeto et al., 2007). Studies have reported that tannins interfere with the uptake of nonheme-iron in consumers and decrease thiamin absorption and the digestibility of starch (Silva and Silva, 1999). They also interfere with lipid and protein digestibility (Bravo, 1998). Oxalates are found in cassava leaves and it is well known that oxalates interfere with calcium uptake (Wobeto et al., 2007). Oxalate a in cassava leaves varies from 1.35 to 2.88 g/100 g dry weight (Correa, 2000; Wobeto et al., 2007).

Cassava toxicity

The most toxic substances found in both cassava roots and leaves are cyanogenic glycosides. The level depends on the genotype as well as environmental factors, for instance drought. Acute poisoning and death following consumption of cassava is rare. Cases that have been reported are mainly associated with undernourishment, marasmus and kwashiorkor (Cock, 1973; FAO/WHO, 2005). In Mozambique, acute poisoning from cassava consumption has, however, been reported in Nampula Province (Essers et al., 1992). To avoid acute toxicity in humans the level of cyanide should be less than 10 mg equivalent/kg dry matter (FAO/WHO, 1991a). Unfortunately, it is estimated that the level of cyanide from cassava, consumed per person in Mozambique, is 14 to 70 times higher based on bodyweight (Burns et al., 2012), than the safety limit proposed by the World Health Organization (FAO/WHO, 1991b).

Chronic poisoning follows long-term consumption of cassava with high cyanogenic glycoside content. This has been reported in countries where cassava is used as staple food, including Mozambique (Dufour, 1988; Mckey and Beckerman, 1993; Ministry of Health Mozambique, 1984; Cliff at al., 1997; Cliff at al., 2011). Chronic intoxication from cassava manifests as tropical neuropathy (Osuntokun, 1994), glucose intolerance and konzo (Ernesto et al., 2002, Cliff at al., 1997; Cliff at al., 2011), goitre and cretinism (Delange et al., 1994).

In Mozambique, konzo is the most common cassava intoxication reported. The first case of konzo was reported in 1981 (Ministry of Health Mozambique, 1984). Population groups found to be most vulnerable are women of child bearing age and children up to two years of age (Cliff et al., 2011). All cases reported in the country have been found to be related to consumption of bitter cassava which was poorly processed, collected during a famine period, during the civil war, or to a diet deficient in sulfur amino acids (Ministry of Health Mozambique, 1984; Essers at al., 1992; Tylleskar er al., 1993; Cliff at al., 1997; Ernesto et al., 2002; Cliff at al., 2011). Patients with konzo have been found to have a high level of thiocyanete in their urine (Ministry of Health Mozambique, 1984; Ernesto et al., 2002; Cliff at al., 2011). Thiocyanate remains in the body as a result of the detoxification of cyanide. It is stored in the stomach and patients with konzo are also at risk to develop stomach cancer (Mirvish, 1983; Maduagwu and Umoh, 1988).

Like anti-nutritional factors, cyanogenic glycosides can be reduced or removed by processing. Processing methods include drying, roasting, boiling, soaking, wetting, and fermentation (Zvauya et al., 2002; Cardoso et al., 2005; Tivana et al., 2007; Cumbana et al., 2007; Tivana et al., 2009). Detoxification processes can be used singularly or in combination. In most cases the combined use of processes results in better nutrient quality (Ikemefuna et al., 1991). A long term approach to the removal of cyanogenic glycosides would be by genetic manipulation to breed less toxic cassava plants (Soetan, 2008). However, this would not solve the problem completely, as environmental factors also play a role.

CONCLUSIONS

This overview consolidates recent publications on the production, consumption and nutritional value of cassava in Mozambique. Many rural parts of Mozambique are remote and lack infrastructure. It is mainly in these deep rural areas that cassava plays an essential role in food security. It is well recognized that the toxic and anti-nutritional factors in cassava threaten food safety in vulnerable populations, particularly during famine or civil unrest in Mozambique. Yet there are affordable traditional ways of reducing and eliminating these toxic compounds and improving the health of rural populations, using traditional cassava products such as *karakata, rale, mahewu* and *oteka*. On a positive note, cassava provides an affordable and accessible source of carbohydrates in Mozambique, as it is easily cultivated, even at subsistence level and is resistant to drought and insects.

The macro-economic impact of cassava flour is particularly important to make bread more affordable, as imported wheat is expensive in a country with a very low Gross Domestic Product and a high level of poverty. More research is required on ways to enrich cassava products, to meet the need for essential nutrients in vulnerable populations, particularly growing children and women of childbearing age, possibly including fortification with essential nutrients such as iron.

ACKNOWLEDGEMENTS

Financial assistance from the South African National Research Foundation and the Graca Machel Scholarship is gratefully acknowledged. Permission to undertake this

study was granted by the Research Ethics Committee of the University of Pretoria (67/2013).

Conflict of interest

The author(s) have not declared any conflict of interest.

REFERENCES

Adewusi SRA, Bradbury JH (1993). Carotenoid in cassava: comparison of open column and HPLC methods of analysis. J. Sci. Food Agric. 62:375-83. http://dx.doi.org/10.1002/jsfa.2740620411

Amoa-Awua W, Frisvad J (1997). Sefa-Dedeh S, Jakobsen M: The contribution of moulds and yeasts to the fermentation of ''agbelima'' cassava dough. J. Appl. Microbiol. 83:288-296. http://dx.doi.org/10.1046/j.1365-2672.1997.00227.x.PMid:9351208

Arguedas PCR (1982). Residual cyanide concentrations during the extraction of cassava starch. Food Technol. 17:251-262. http://dx.doi.org/10.1111/j.1365-2621.1982.tb00180.x

Bandna C (2012/2013). Effect of processing on the cyanide content of cassava products in Fiji. JMBFS 2(3):947-958.

Best RTRH (1993). Cassava: The latest facts about an ancient crop. CIAT publication, Cali, Colombia. Bokanga M (1994). Distribution of cyanogenic potential in the cassava germoplasm. Acta Hortic. 375:117-123.

Boonnop K, Wanapat M, Nontaso N, Wanapat S (2009). Enriching nutritive value of cassava root by yeast fermentation. Sci. Agric (Piracicaba, Braz), 66(5):629-633.

Bradbury JH, Holloway WD (1988). Chemistry of tropical root crops: significance for the nutrition and agriculture in the Pacific. Austr. Centre. Int. Agric. Res. (ACIAR). 6:1-20.

Bradbury JH (2006). Simple wetting method to reduce cyanogen content of cassava flour. J. Food Compost. Anal. 19:388-393. http://dx.doi.org/10.1016/j.jfca.2005.04.012

Bravo L (1998). Polyphenols: chemistry, dietary sources, metabolism, and nutritional significance. Nutr. Rev. 56:317-33. http://dx.doi.org/10.1111/j.1753-4887.1998.tb01670.x.PMid:9838798

Buitrago A (1990). La yuga en la alimentacion animal. Centro Internacional de Agricultura Tropical (CIAT). Cali, Colombia. pp. 10-18.

Burns AE, Gleadow RW, Zacarias AM, Cumbana CE, Miller RE, Cavagnaro TR (2012). Variation in the chemical composition of cassava (*Manihont esculenta*, Crantz) leaves and roots as affected by genotypic and environmental variation. J. Agric. Food Chem. 60:4946-4956.http://dx.doi.org/10.1021/jf2047288. PMid:22515684

Cardoso AP, Mirione E, Ernesto M, Massaza F, Cliff J, Haque MR, Bradbury JH (2005). Processing of cassava roots to remove cyanogens. J. Food Compost Anal. 18:451-460. http://dx.doi.org/10.1016/j.jfca.2004.04.002

Charles AL, Chang YH, Ko WC, Sriroth K, Huang TC (2004). Some physical and chemical properties of starch isolates of cassava genotypes. Starch-Starke. 56(56):413-418. http://dx.doi.org/10.1002/star.200300226

Charles AL, Sriroth K, Huang TC (2005). Proximate composition, mineral contents, hydrogen cyanide and phytic acid of five cassava genotypes. Food Chem. 92:615-620. http://dx.doi.org/10.1016/j.foodchem.2004.08.024

Chiwona-Karltun L, Mkumbira J, Saka J, Bovin M, Mahungu NM, Rosling H (1998). The importance of being bitter – a qualitative study on cassava cultivar preference in Malawi. Ecol. Food Nutr. 37:219-245. http://dx.doi.org/10.1080/03670244.1998.9991546

Chiwona-Karltun L, Tylleskar T, Mkumbira J, Gebre-Medhin M, Rosling H (2000). Low dietary cyanogen exposure from frequent consumption of potentially toxic cassava in Malawi. Int. J. Food Sci. Nutr. 51:33-43. http://dx.doi.org/10.1080/096374800100886. PMid:10746103

Chiwona-karltun L, Brimer L, Kalenga SJD, Mhone AR, Mkumbira J, Johansson L, Bokanga M (2004). Bitter taste in cassava roots correlates with cyanogenic glucoside levels. J. Sci. Food Agric. 84:581-590. http://dx.doi.org/10.1002/jsfa.1699

Cliff J (1994). Cassava safety in times of war and drought in Mozambique. Acta Hortic. (ISHS) 375:373-378.

Cliff J, Nicala D, Saute F, Givragy R, Azambuja G, Taela A (1997). Konzo associated with war in Mozambique. Trop. Med. Int. Health. 2:1068-1074. http://dx.doi.org/10.1046/j.1365-3156.1997.d01-178.x PMid:9391509

Cliff J, Muquingue H, Nhassico D, Nzwalo H, Bradbury JH (2011). Konzo and continuing cyanide intoxication from cassava in Mozambique. Food Chem. Toxicol. 49:631-635. http://dx.doi.org/10.1016/j.fct.2010.06.056. PMid:20654676

Cock JH (1973). Cyanide toxicity in relation to the cassava research program of CIAT in Colombia. In ME Nestel B (eds), Chronic cassava toxicity. Proceedings of the interdisciplinary workshop edn. Ottawa: International Development Research Centre. pp. 37-40.

Correa AD (2000). Farinha de folhas de mandioca (*Manihot esculenta* Crantz cv. Baiana) efeito de processamentos sobre alguns nutrients e antinutrientes. 108f. Tese (Doutorado em Ciências de Alimentos). Lavras, Brazil: Univ. Federal de Lavras.

Cumbana A, Mirione E, Cliff J, Bradbury JH (2007). Redution of cyanide contents of cassava flour in Mozambique by wetting method. Food Chem. 101:894-897. http://dx.doi.org/10.1016/j.foodchem.2006.02.062

Delange F, Ekpechi LO, Rosling H (1994). Cassava cyanogenesis and iodine dificiency disorders. Acta Hortic. 375:289-293.

Donovan C, Haggblade S, Salrgua AV, Cuambe C, Mudema J, Tomo A (2011). Cassava commercialization in Mozambique. MSU International development working . 120:1-59.

Dufour DL (1988). Cyanide content of cassava (*Manihot esculenta*, Euphorbiaceae) cultivars used by Tukanoan Indians in Northwest Amazonia. Econ. Bot. 42:255-266. http://dx.doi.org/10.1007/BF02858929

El-Sharkawy MA (2004). Cassava biology and physiology. Plant Mol. Biol. 56:481-501. http://dx.doi.org/10.1007/s11103-005-2270-7 PMid:15669146

Ernesto M, Cardoso AP, Nicala D, Mirione E, Massaza F, Cliff J, Haque Mr, Bradbury JH (2002). Persistent Konzo and cyanide toxicity from cassava in Northern Mozambique. Acta Trop. 82:357-362. http://dx.doi.org/10.1016/S0001-706X(02)00042-6

Essers AJA, Alsen P, Rosling H (1992). Insufficient processing of cassava induced acute intoxications and the paralytic disease konzo in rural area of Mozambique. Ecol. Food Nutr. 27:172-177. http://dx.doi.org/10.1080/03670244.1992.9991222

Factfish (2014) Mozambique cassava. Available online: http://www.factfish.com/statistic-country/mozambique/cassava Accessed on 04 Jun 2014.

FAO/WHO (1991a). Joint FAO/WHO food standard programme. Codex Alimentarius commission. XII Suppl. 4 Ed. Rome: FAO. pp. 1-42.

FAO/WHO (1991b). Joint FAO/WHO food standard programme: In: Codex Alimentarius Commission XII.

FAO/WHO (2005). Codex standard for sweet cassava. In Codex standard, (eds), Joint FAO/WHO Food standard programmer: Codex Alimentarius Commission. Rome: FAO/WHO. 238-2003.

FAO/WFP (2010). Crop and food security assessment to Mozambique.

FAO (2011a). Food outlook. Global market analysis, global information and early warning system on food and agriculture. Rome: FAO. 1-109.

FAO (2011b). Nutrition country profile of Mozambique. Rome: FAO.

FAOSTAT (2011a). Food balance sheet. Available online: http://www.faostat.fao.org Accessed on 20 Jun 2012.

FAOSTAT (2011b). Mozambique country profile. Available online: http://wwwfao.org/corp/statistics/en/ Accessed on 20 November 2013.

Favier JC (1977). Valeur alimentaire de deux aliments de base Africains: le manioc et le sorgho. Paris, France: ORSTOM (editions de l'Office de la Recherche Scientifique et Technique Outre-mer). Travaux et documents nr 67. Available from: http://www.congoforum.be/upldocs/manioc.pdf. Accessed on 07 December 2013.

Gade D (2003). Names for Manihot esculenta: Geographical variation and lexical clarification. JLAG. 1:43-57.

Gbadegesin MA, Olaiya CO, Beeching JR (2013). African cassava:

Biotechnology and molecular breeding to the rescue. Br Biotechnol J. 3(3):305-317. http://dx.doi.org/10.9734/BBJ/2013/3449
Gil JL, Buitrago AJA (2002). La yuga en la alimentacion animal. In: Osopina B, Ceballos H, (Eds). La yuga en el tercer milénio: sistemas modernos de produccion, procesamiento, utilizacion y comercializacion. Cali, Colombia: CIAT: pp. 527-569. Available online: http://www.clayuca.org/PDF/libro-yuca/capitulo28.pdf Accessed on 29 Jun 2012.
Hagglades S, Cumbana C, Donovan C, Droppimunn K, Jirstrom M (2012). Assava commercialization in Southeastern Africa. JADEE. 2(1):4-40.
Hambidge KM, Miller LV, Westcott JL, Krebs NF (2008). Dietary reference intakes for zinc may require adjustment for phytate intake based upon model predictions. J. Nutr. 138:2363-6. http://dx.doi.org/10.3945/jn.108.093823. PMid:19022958 PMCid:PMC2635502
Hoguane AM (2007). Diagnosis of Mozambique coastal zone. JICZM. 7(1):69-82.
Howard J, Crawford C, Kelly V, Demeke M, Jeje JJ (2003). Promoting high-input maize technologies in Africa: the Sasakawa-Global 2000 experience in Ethiopia and Mozambique. Food Policy. 28:335-348. http://dx.doi.org/10.1016/j.foodpol.2003.08.008
Hudson BJF, Ogunsua OA (1974). Lipids of cassava tubers (*Manihot esculenta,* Crantz). J. Sci. Food Agric. 25:1503-1508. http://dx.doi.org/10.1002/jsfa.2740251210. PMid:4437153
IFAD/FAO (2005). Proceedings of the validation forum on the global cassava development strategy: A review of cassava in Africa with country case studies on Nigeria, Ghana, the United Republic of Tanzania, Uganda and Benin. 2:1-66.
Ikemefuna C, Obizoba J, Atii JV (1991). Effects of soakin, sprouting, fermentation and cooking on nutrient composition and some antinutritional factors of sorghum (Guinesia) seeds. Plant. Food Hum. Nutr. 41:203-212. http://dx.doi.org/10.1007/BF02196388
IIAM/PNRT (2007). Potential production areas of cassava in Mozambique. Maputo, Mozambique: MINAG.
INE (Instituto Nacional de Estatísticas) (2009). Apresentação dos resultados definitivos do censo 2007 (Presentation of the final results of the census 2007). Available online: http://www.ine.gov.mz/censo2007/censo2007 Accessed on 12 May 2012.
INE (Instituto Nacional de Estatíscas) National institute of Statistics. Censo Agro-pecuário (Agriculture and Livestock Census) 2009-2010: Resultados definitivos (Definitive results) (2011). Available online: http://www.ine.gov.mz/censos_dir/agro-pecuaria/CAP_VF.pdf. Accessed on 03 Jun 2014.
INIA (Instituto Nacional de Investigação Agrária) (1994). Zonas agras ecológicas de Moçambique (Agro-ecological zones of Mozambique). Maputo, Mozambique: INIA.
INIA (Instituto Nacional de Investigação Agrária)/IITA/SARRNET (2002). Cassava and sweet potato production, processing and markiting in Mozambique. Maputo, Mozambique: INIA.
IOF (2008/09). Mozambique household budget and expenditure survey.
Lancaster PA, Ingram JS, Lim MY, Coursey DG (1982). Traditional cassava-based foods: survey of processing techniques. Econ. Bot. 36:12–45. http://dx.doi.org/10.1007/BF02858697
Mader (Ministério de Agricultura e Desenvolvimento Rural) (2005). Trabalho de inquérito agrícola 2005 (National Agricultural Survey 2005). National Agricultural survey Maputo, Mozambique: Mader.
Maduagwu EN, Umoh IB (1988). Dietary thiocyanate and N-nitrosation in vivo in wistar rat. Ann. Nutr. Metab. 32(1):30-37. http://dx.doi.org/10.1159/000177389. PMid:3355109
Marfo EK, Simpson BK, Idowu JS, Oke OL (1990). Effect of local food processing on phytate levels in cassava, cocoyam, yam, maize, sorghum, rice, cowpea, and soybean. J. Agric .Food Chem. 38:1580-1585. http://dx.doi.org/10.1021/jf00097a032
Mckey D, Beckerman S (1993). Chemical ecology, plant evolution and traditional manioc cultivation systems. *In* Hladik CM, Hladik A, Linares OF, Pagezy H, Semple A, Hadley M [eds], Tropical forests, people and food: Biocultural interactions and applications to development, pp. 83–112. UNESCO, Paris, France, and Parthenon, Canforth, UK.
Mckey D, Cavagnaro TR, Cliff J, Gleadow R (2010). Chemical ecology in coupled human and natural systems: People, manioc, multitrophic interactions and global change. Chemoecology 20:109-133. http://dx.doi.org/10.1007/s00049-010-0047-1
Mkumbira J, Chiwona-Karltun L, Lagercrantz U, Mahungu NM, Saka J, Mhone A, Bokanga M, BrimerL, Gullberg U, Rosling H (2003). Classification of cassava into 'bitter' and 'cool' in Malawi: from farmers' perception to characterization by molecular markers. Euphytica. 132:7-22. http://dx.doi.org/10.1023/A:1024619327587
MIC (Ministério do Comercio) /FAO/EC (2004). External market task force: Report on cassava. 3(1):1-90.
MIC (Ministério de Comercio) (2007). Cassava development strategy for Mozambique 2008-2012. Maputo, Mozambique: MIC.
Ministry of Health Mozambique (1984). Mantakassa: an epidemic of spastic paraparesis associated with chronic cyanide intoxication in a cassava staple area of Mozambique: epidemiology and clinical and laboratory findings in patients. Bull. World Health Org. 62:477-484.
Mirvish SS (1983). The etiology of gastric cancer, intr-gastric nitrosamide formation and other theories. J. Nat. Cancer. Inst. 71:630-636.
Montagnac JA, Davis CR, Tanumihardjo SA (2009a) Reduce toxicity and anti-nutrients of cassava for use as a staple food. Compr. Rev. Food Sci. Saf. 8:17-27.
Montagnac JA, Davis CR, Tanumihardjo SA (2009b) Nutritional value of cassava for use as a staple food and recent advances for important. Compr. Rev. Food Sci. Saf. 8:181-194. http://dx.doi.org/10.1111/j.1541-4337.2009.00077.x
Mowat L (1989). Cassava and chicha: Bread and beer of the Amazonian Indians. Shire Publications, Aylesbury, UK.
Nambisan B, Sundareson S (1985). Effect of processing on the cyanoglucosidr content of cassava. J. Sci. Food Agric. 36:1197-1103. http://dx.doi.org/10.1002/jsfa.2740361126
Nambisan B, Sundareson S (1994). Distribution of linamarin and its metabolizing anzimes in cassava tissues. J. Sci. Food Agric. 66:503-507. http://dx.doi.org/10.1002/jsfa.2740660413
Nhassico D, Muquingue H, Cliff J, Cumbana A, Bradbury JH (2008). Review Rising African cassava production, diseases due to high cyanide intake and control measures. J. Sci. Food Agric. 88:2043-2049. http://dx.doi.org/10.1002/jsfa.3337
Nielson HH (2009). The role of cassava in smallholder maize marketing in Zambia and Mozambique. Michigan State University.
Okigbo BN (1980). Nutritional implication of projects giving high priority of the production of staples of low nutritive quality. In the case of cassava (Manihont esculenta, Crantz) In the humid tropics West Africa. Food Nutr. Bull. 2:1-10.
Osuntokun BO (1994). Chronic cyanide intoxication of dietary origin and a degenerative neuropathy in Nigerians. Acta Hortic. 375:311-321.
Oyewole OB (2001). Characteristics and significance of yeast involvement in cassava fermentation for '*fufu*' production. Int. J. Food Microbiol. 65:213-218. http://dx.doi.org/10.1016/S0168-1605(01)00431-7
Rawel HM, Kroll J (2003). Importance of cassava (*Manihot esculenta* Crantz) as the main staple food in tropical countries. DLR. 99:102-110.
Salegua V, Donavan C, Haggblades S, Cuabe C, Nhatumbo A (2012). Dinâmica da cadeia de valores da mandioca no Norte de Moçambique (Dynamics of the cassava value chain in the North Mozambique) IIAM Boletim Nordeste. 1:1-7.
Silva MR, Silva MAAPd (1999). Nutritional aspects of phytates and tannins. Revista de Nutrição. 12:21-32.
Singh M, Krikorian AD (1982). Inhibition of trypsin activity *in vitro* by phytate. J. Agric. Food Chem. 30:799-800. http://dx.doi.org/10.1021/jf00112a049
Siritunga D, Sayre RT (2003). Generation of cyanogen-free transgenic cassava. Planta. 217:367-373. http://dx.doi.org/10.1007/s00425-003-1005-8. PMid:14520563
Soetan KO (2008). Pharmacological and other beneficial effects of antinutritional factorsin plants. Afr. J. Biotechnol. 7(25):4713-4721.
Tewe OO (2004). Cassava for livestock feed in sub-Saharan Africa. FAO/FAD. 1255:1-64.
Tivana LD, Bvochora JM, Mutukumira AN, Owens JD (2007). A study of heap fermentation processing of cassava roots in Nampula Province, Mozambique. J. Root Crops. 33(2):118-128.

Tivana LD, Da Cruz FJ, Bergenstahl B, Dejmek P (2009). Cyanogenc potential of roasted cassava (*Manihot esculenta* Crantz) roots r*ale* from Inhambane Province, Mozambique. Czech. J. Food Sci. 27:S375-S378.
Tivana LD (2012). Cassava processing: Safety and protein fortification, Lund University.
Tostao E, Wade BB (2005). Spatial efficiency in Mozambique's post-reform maize markets. Agricultural Economics, Int. Assoc. Agric. Econ. (IAAE). 33(2):205-214. http://dx.doi.org/10.1111/j.1574-0862.2005.00262.x
Tschirley D, Abdula D, Weber MT (2006). Toward improved maize marketing and trade policies to promote household food security in Central and Southern Mozambique. Research Report 60E, Ministry of Agriculture, Republic of Mozambique.
Tylleskar T, Howlett WP, Rwiza HT, Aquilonius SM, Stalberg E, Linden B (1993). Konzo: a distinct disease entity with selective upper motor neuron damage. J. Neurol. Neurosurg. Psychiatry 56:638-643. http://dx.doi.org/10.1136/jnnp.56.6.638. PMid:8509777 PMCid:PMC489613
UNDP (2010) Human development report 2010. The real wealth of nations: pathways to human development. Palgrave MacMillan, Basingstoke.
USDA National Nutrient Database for Standard Reference. Available from: http://www.nal.usda.gov/fnic/foodcomp/search/. Accessed on 10 July 2013.
Walker T, Pitoro R, Tomo A, Sitoe I, Salência C, Mahanzule RC. Donovan C, Mazuze F (2006). Priority setting for public-sector. Agricultural Research in Mozambique with the National Agricultural Survey Data. Research report No. 3E. Institute of Agricultural Research of Mozambique. Maputo: Mozambique.
West CE, Pepping F, Temalilwa CR (1988). The composition of foods commonly eaten in East Africa. The Netherlands: Wageningen Agricultural University.
Wobeto C, Correa AD, de Abreu CMP, dos Santos CD, de Abreu JR (2006). Nutrients in the cassava (*Manihot esculenta*, Crantz) leaf meal at three ages of the plant. Cienc. Technol Aliment. 26:865-869. http://dx.doi.org/10.1590/S0101-20612006000400024
Wobeto C, Correa AD, de Abreu CMP, dos Santos CD, Pereira HV (2007). Antinutrients in the cassava (*Manihot esculenta* Crantz) leaf powder at three ages of the plant. Cienc Technol Aliment. 27:108-112. http://dx.doi.org/10.1590/S0101-20612007000100019
Woot-Tsuen WL, Busson F, Jardin C (1968). Food composition table for use in Africa. FAO corporate document repository. Rome, Italy. Available online: http://www.fao.org/docrep/003/X6877E/X6877E00.htm#TOC. Accessed on 20 November 2013.
Zvauya R, Ernesto M, Bvochora T, Tivana LD, Da Cruz FJ (2002). Effect of village processing methods on cyanigenic potential of cassava flour collected from selected districts of Nampula Province in Mozambique. Int. J. Food Sci. Technol. 37:463-469. http://dx.doi.org/10.1046/j.1365-2621.2002.00584.x