DEDICATION

To my father, Mr.AWUNJUAH Johnes, my mum, Mrs. AKAWUNG Osla and to my Brothers, Sisters, Nephews and Nieces.

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- I will start by thanking the almighty God for granting me the breath and the health to go through this work successfully and making available all those who assisted me in the accomplishment of this task.
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Abbreviations

(IITA) International Institute of Tropical Agriculture

(SSA) Sub-Saharan Africa

ANOVA: Analyses of Variances

AACC: American Association of Cereal Chemists

FAOSTAT: Food and Agricultural Organization Statistics

DM: Dry matter

FAOSTAT: Food and Agricultural Organization Statistics

RVA: Rapid Visco-Analyser

WACr: Real Water Absorption Capacity

WHO: World Health organization

SI : Solubtiliy index

CMV : Cassava Mosaic Virus

ENSAI : Ecole Nationale Supérieure des Sciences Agro-Industrielles

mg/kg: milligrams per kilogram

HCN: Hydrocyanic acid

MW: Molecular weight

HCL: hydrochloric acid

KOH: Potassium hydroxide

rpm : revolutions per minute

OD: optical density

LGC: Least gelation concentration

ABSTRACT

Improved and local cassava roots of 41 cultivars from some localities in Cameroon (Mbama, Ekondotiti, South, Foreke-Dschang, Foto-Dschang, Fongo-ndeng Dschang, Santchou-Dschang, Fotesa-Dshang) and Chad (Berekouh, Mboura, Daradja, Kamkoutou) were analysed for some physicochemical, functional and pasting properties. Variations were observed in the physicochemical properties of the different varieties; starch content ranged from 65.07 - 90.85%; amylose 12.13- 20.82%;cyanide 9.31-126.04mg/kg; amylopectin 79.18-87.87%; ash1.55-3.64%;dry matter 80.83-90.50% ; and moisture 9.5-19.17%. Functional properties of the cassava roots sample; water absorption capacity ranged from127.73–365.99 %; solubility index 10.75-34.67; and the least gelation concentration 12-16%.Significant differences ($P < 0.05$) were observed in the functional properties of the cultivars. The peak viscosity ranged from 1338 to 3797 cP. Variety TMS 633397 Blanc from Foto-dschang gave the highest 3797cP while variety Baga from Berekouh gave the lowest value 1338 cP.The breakdown viscosity ranged from 416cP to 2120cP. TMS 3001 Rouge Claire longue feuilles from Foreke-dschang had the highest 2120cP whereas variety Balbine from Mbama had the lowest value 416cP.The final viscosity ranged from 384- 3234cP. Variety TMS 633397 had the highest (3234cP) , while variety Berekouh had the lowest (384cP). These varieties were gotten from Fongo-ndeng dschang and Berekouh respectively. The setback viscosity ranged between 86 -1279cp. with TMS3001 rouge claire longue feuille having the highest (1279cP) and Berekouh having the lowest (86cP).The pasting temperature ranged from 50.26°C for variety Balbine from Mbama to 70.95°C for variety TME from Mboura. There were significant differences ($P < 0.05$) in the pasting properties of the cassava roots samples.

Key words: Cassava, varieties, characterization, physico-chemical, functional and pasting properties. RVA

CHAPTER 1

GENERAL INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is a perennial woody shrub with an edible root, which grows in tropical and subtropical areas of the world. The leaves and roots are consumed by people in different parts of the world. The starchy tuberous roots of cassava provide more than half of the calories consumed by more than 800 million people in Sub-Saharan Africa (SSA), Latin America and Asia (Shore, 2002). Cassava has become the most important source of dietary energy in SSA (Scott *et al.*, 2000) as it provides more dietary energy per hectare and working hours than any other staple crop (Akoroda, 1995; Fregene *et al.*, 2000; Nassar, 2005). Other advantages of cassava include flexibility in planting, harvesting time, and drought tolerance. The ability of cassava to grow and produce on low nutrient soils, where cereals and other crops do not grow well, and suitability for incorporation in various cropping systems are the other advantages of cassava (Onwueme, 1978; Fregene *et al.*, 2000; Nassar, 2005). Leaves of cassava are used as a vegetable in Africa and are a cheap but rich source of proteins, vitamins A, B and C, and other minerals (Hahn, 1988; FAO, 1993; Moyo *et al.*, 1998; Fregene *et al.*, 2000; IITA, 2001). These attributes make cassava a mainstay of smallholder farmers in the tropics with limited access to agricultural inputs (Fregene *et al.*, 2000). Most smallholder farmers grow a number of cultivars, each with locally preferred characteristics such as taste, early maturity, pests and disease s resistance, and/or processing characteristics (Salick *et al.*, 1997; Chiwona-Karltun *et al.*, 2000; Mkumbira *et al.*, 2001). It is one of the most important food crops in the tropics (Lasekan *et al.*, 2004; Burrell, 2003), ranked third after rice and corn for food staples (Kasi *et al.*, 2012; Kobawila *et al.*, 2005) and serves as a food security and income generation crop for many millions of people in the developing world (Scott *et al.*, 2002). It is grown across the world and is a staple food crop for more than 30% of the world's population. Cassava is used as an important food supplement, a main part of breakfast and a snack in many parts of the world (FAO, 1993; Sauti *et al.*, 1994; Moyo *et al.*, 1998).Cassava is becoming an important cash crop for smallholder farmers, middlemen as well as sellers in various markets and is increasingly becoming an important industrial crop (Sauti *et al.*, 1994; Moyo *et al.*, 1998; Benesi *et al.*, 2001a; 2001b; Benesi, 2002; Benesi *et al.*, 2004). Cassava roots are an excellent source of carbohydrates but contain very little proteins. The use of cassava roots as food is not only limited by its low protein content but also by its perishability and potential toxicity (Irtwange

and Achimba, 2009; King and Bradbury, 1995) as they contain cyanogenic glucosides namely linamarin (95%) and 5% lotaustralin (methyl linamarin) .These cyanogenic glucosides, together with their breakdown products (cyanohydrins and free HCN) formed during processing, can cause health problems such as goiter, dwarfism and tropical ataxic neuropathy (Kobawila *et al.*, 2005), vomiting, nausea, dizziness, stomach pain, body weakness, headache and diarrhoea and occasionally death (Akintonwa *et al.*, 1994). It is almost certainly the cause of konzo (epidemic spastic paraparesis) in eastern, central and southern Africa (Allen, 2010; Ernesto *et al.*, 2002), which is an irreversible paralysis of the legs and occurs particularly in children and women of child-bearing age. In order to overcome the aforementioned drawbacks of cassava roots, various processing methods (varying from cultural to geographical locations) have been described (Uyoh *et al.*, 2009) and include; fermentation (submerged and solid-state), boiling, drying (Irtwange and Achimba, 2009), steam distillation, among others, with fermentation being the most popular and widely used means of processing (Nambisan, 2011; Oyewole,1992). These processes therefore help to convert cassava roots to final stable products with a consequent cyanide reduction (Nambisan, 2011; Oyewole, 1992).

Starch is the major component of the cassava root and its use is primarily determined by its physicochemical properties (Onitilo et al 2007).Cassava starch is processed into various pregelatinised instant and convenience foods which include gari, fermented cassava flour, and fufu. All these differ in their pasting characteristics, which are determined by the varieties of cassava and the processing methods employed (Sanni et al 2003, Onitilo et al 2007, Etundaiye et al 2009). Starches (Madsen & Christensen, 1996). from various plant sources, such as corn, potato, wheat, cassava and rice, have received extensive attention in relation to structural and physico-chemical properties (Identification of native starch sources is required for desired functionality and unique properties (Duxbury, 1989). The physico-chemical properties and functional characteristics that are imparted by the starches to the aqueous systems and their uniqueness in various food applications vary with the biological origin (Svegmark & Hermansson, 1993). Starch contributes greatly to the textural properties of many foods and has many industrial applications as a thickener, colloidal stabilizer, gelling agent, bulking agent, water retention agent and adhesives origin (Svegmark & Hermansson, 1993). Its unique properties also include high paste viscosity, high paste clarity, which are advantageous to many industries. (Oyewole and Obieze 1995).

Cassava starch consists primarily of D-glucopyranose polymers linked by α-1, 4 and α-1, 6 glucosidic bonds called amylose and amylopectin respectively (Wurzburg, 1986a; Thomas and Atwell, 1999). The level of amylose and amylopectin found in cassava starch depends upon the variety from which starch was extracted (Wurzburg, 1986a). Rickard and his colleagues in their work on cassava starch from fresh roots reported an amylose range of 13.6–23.8% .Moorthy and Matthew (2000) reported amylose content ranging from 22.6% to 26.2%. Dakubu and Bruce-Smith established that starches from fully matured cassava varieties had normal amylose content which varied from the range of 13.6 – 19.1%. While Aryee (2006) reported high amylose content of 44.3% on cassava flour. Amylose content determines the stability of a viscous solution formed when heat is applied.

Although cassava mean composition is known, Variations in chemical composition of the different cassava varieties would influence to varying levels their organoleptic, functionality and physicochemical properties during their applications in food and industrial processing, thus the general objective of this work is;

To characterize the different cassava varieties for their physicochemical and functional point of view so that results from these analysis would be beneficial in selecting cassava varieties for specific food processing, industrial applications, and grouping. With specific objectives being;

1. Analyse the different cassava varieties

2. Compare the physicochemical and functional properties of these varieties

3. Come out with a functional and toxic cartography of these varieties based on their regions of origin

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The cassava is an important component in the diets of more than 800 million people around the world (FAO, 2007) and is the third largest carbohydrate food source within the tropical regions, after rice and corn (Ceballos *et al.*, 2004). Cassava is referred to as a food security crop (Barratt *et al.*, 2006), It is used mainly as a fresh food item, but is also processed into various food and non-food products, such as starch, flour, beverages, animal feeds, biofuels and textiles. It is widely recognized as a productive crop and a good energy source (670KJ/100g sample) (Adebayo-Oyetoro *et al.*, 2013; Osakwe *et al.*, 2008). This plant is one of the most drought-tolerant crops; capable of growing on marginal soils where very little can grow. There is much variation in the nutrient quality of the cassava root (Chaves *et al.*, 2005). The starch content of the fresh cassava root is about 30%, and gives the highest yield of starch per unit area of any crop known (Tonukari, 2004). The protein content is extremely low, however, and ranges between 1-3% (Buitrago, 1990; Salcedo *et al.*, 2010). There are several thousand varieties of cassava and about 100 related wild species (Hershey *et al.*,1997), with hydrogen cyanide (HCN) contents of their roots ranging from 1-1550 parts per million (ppm) (Cardoso *et al.*, 2005). Cassava plants are generally categorised as bitter or sweet, depending upon their cyanide content. The low-HCN, or sweet cassava, has less than 50 ppm of cyanogenic equivalents, while the high-HCN or bitter cassava has more than 100 ppm (Wilson and Dufour, 2002). According to Adepoju *et al.*, (2010), the food value of cassava is greatly compromised by its toxic hydrogen cyanide content. The sweet cassava can be cooked and eaten as they are, while the bitter cassava needs to be processed before being consumed.

These varieties of cassava, are differently use for the production of many cassava products. The properties which people want for a specific cassava product are different. So a good knowledge about cassava roots properties (physico-chemical and functional properties) will go a long way help to choose specific cassava varieties for specific product, and so add more economic importance to cassava. It is from this aforementioned problem that this work is based.

2.2 Origin of cassava

It appears to have originated in Brazil and Paraguay but has spread throughout tropical areas of South and Central America long before the arrival of Columbus (Ecoport, 2009). It is now one of the most important food crops in tropical countries throughout the world and it is ranked as the third most important food crop worldwide, even though in western countries it is little known or used. FAOSTAT (2012) reported that Nigeria is the world's largest producer of cassava, followed by Indonesia and Brazil.

2.2.1 Taxonomy of cassava

Cassava (Manihot esculenta Crantz), a single species, belongs to the family Euphorbiaceae. Of the 98 species that belong to the genus Manihot, cassava is the only species that is widely cultivated for food production (Rogers and Appan, 1973; Onwueme, 1978; Mkumbira, 2002; Nassar, 2005). Cassava cultivars have been classified according to morphology, e.g. leaf shape and size, plant height, stem and petiole colour, inflorescence and flower colour, root shape and colour, and content of cyanogenic glucoside in the roots (Onwueme, 1978; Mkumbira, 2002; Nassar, 2005). Cyanogenic glucoside has been used to place cassava cultivars into two major groups: bitter cultivars, in which the cyanogenic glucoside is distributed throughout the tuberous root, at levels higher than 100mg/kg dry root weight, and sweet/cool varieties, in which the cyanogenic glucoside at low levels is confined mainly to the peel. The flesh of sweet/cool varieties is therefore relatively free of cyanogenic glucoside (Mkumbira, 2002; Nassar, 2005).

Early literature on cassava therefore described the genus as having two edible species, Manihot utilissima Phol and Manihot aipi Phol delineating cultivars with high and low cyanogenic glucoside concentration respectively. Cassava has recently been classified as being one species, Manihot esculenta Crantz (Onwueme, 1978).

Cassava is scientifically classified as follows:

Kingdom:	Plantae
Phylum:	Angiospermophyta
Sub-phylum:	Eudicots
Class:	Rosids(dicotyledon)
Order:	Malpighiales
Family:	Euphorbiaceae
Sub-family:	Crotonoideae
Tribe:	Manihoteae
Genus*:*	*Manihot*
Species:	*Manihot esculenta*
Binomial name:	*Manihot esculenta* Crantz.

2.2.2 Ecology

The cassava plant is one of the most forgiving and adaptable plant. It grows well in tropical humid conditions but can also withstand droughts and marginal lands and even in poor soils where little else will grow (Vongsamphanh and Wanapat, 2004). It, however, does not grow well in heavy rocky and gravelly soils (Heuzé *et al.*, 2012). It requires little care and protects itself against predators by means of poisonous latex which is particularly evident in the leaves. It is an ideal food crop for tropical growing conditions.

2.2.3 Cultivation

Cassava is grown widely in several parts of the world especially in the tropical regions and constitutes a significant proportion of the diet of the population (Tetchi *et al.*, 2012). It is mostly cultivated in tropical areas because of its high suitability for growing in marginal climatic and soil fertility conditions with a high productivity per unit area (Reginier *et al.*, 2010). Cultivation is carried out throughout the lowland tropics typically between 30^{o}N and

30°S of the equator, in areas where the annual mean temperature is greater than 18°C. In Africa, cassava is usually grown in mixed stands with other crops such as maize, beans, cocoyams and sorghum (Hillocks *et al.*, 2002).

Cassava culture can face the problems of pathogens, diseases and pests which considerably reduce its yields. They include: elegant grasshopper, root mealy bug, root rots, Cassava Green Mites (CGM), cassava mealy bug, Cassava Mosaic Virus(CMV) and Cassava Bacterial Blight(CBB) (Hillocks *et al.*, 2002), Blight Leaf Spot (BILS), Brown Leaf Spot (BLS), White Leaf Spot (WLS), Cassava Brown Streak Virus Disease (CBSD), nematodes, root and tuber scale (Nassar and Ortiz

a **b**

Fig 1.a Cassava plants growing in the field (IITA website, www.iita.org). b Freshly harvested cassava root (IITA website, www.iita.org)

2.2.4 Production of Cassava Roots

World production of cassava roots was estimated to be 184 million tonnes in 2002, rising to 230 million tonnes in 2008 (FAO, 2008). Among food crops, cassava is the 9th in terms of quantity produced worldwide (FAOSTAT, 2012). Nigeria is the world's largest producer of cassava (FAOSTAT, 2012; FAO, 2012); this is followed by Indonesia and Brazil respectively. Cameroon is ranked number 16 in terms of world production of cassava (FAOSTAT, 2012). Meanwhile at national production level, this root crop is ranked 1st among food crop production, followed by plantain and maize (FAOSTAT, 2012).

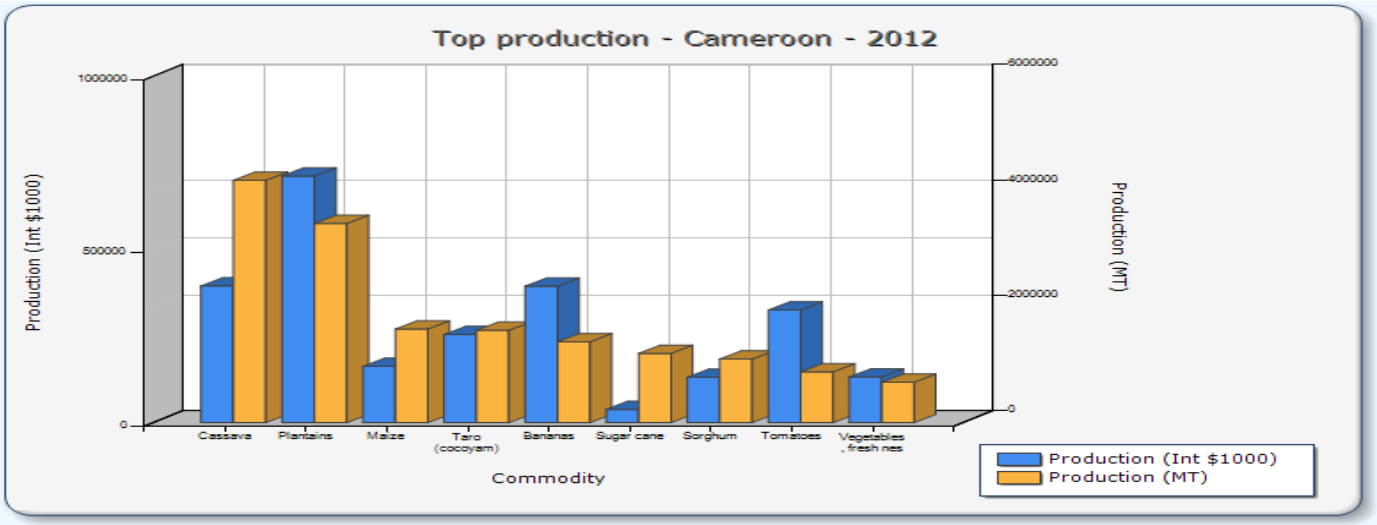

Figure2: Food crop production in Cameroon (source: FAOSTAT, 2012).

2.2.5 Chemical Composition of the Cassava Root

The chemical composition of cassava roots is shown below. The composition of peel and parenchyma is different: the peel has more protein, fibers, and sugars, than the parenchyma, and less dry matter and starch. A wide range of values is reported in the literature for each root component. Whole-root dry matter contents vary from 20% to 40% and between 70% and 90% of dry matter are composed of starch, with average values between 80% and 85% (Alfredo, 2002). Total carbohydrates, including starch, free sugars, and other cellulose or hemicellulose components, together make up over 90% of parenchyma dry weight (Alfredo, 2002).

The protein content is uniformly low (below 2% on a fresh-weight basis), as are fats and ash contents. The fiber contents are more variable, and increase with plant age. A great variation in total cyanogen content also exists, with parenchyma values of 30–100mgkg^{-1} common for low-cyanogenic cultivars destined for direct consumption, compared to 1350mgkg^{-1} in industrial varieties used for processing.Table 1 shows the constituents of cassava root parenchyma and peel.

Table 1: Constituents of cassava root parenchyma and peel

Constituents	Percentage (%) of dry weight	
	Parenchyma	**Peel**
Dry matter (%, fresh weight)	23 – 44	15 – 34
Starch	70 – 91	44 – 59
Total sugars	1.3 – 5.3	5.2 – 7.1
Crude fiber	3.0 – 5.0	5.0 – 15.0
Ash	1.0 – 2.5	2.8 – 4.2
Proteins	1.0 – 6.0	7.0 – 14.0
Fat	0.3 – 2.5	1.5 – 2.8

(Source: Alfredo, 2002)

Table 2**: Vitamin, mineral, and cyanide constituents of cassava root parenchyma and peel**

Constituents	Milligrams per kilogram (mg/kg) dry weight	
	Parenchyma	**Peel**
Total cyanide	**30 – 1350**	**60 – 500**
Calcium	480 – 920	44 – 59
Phosphorus	770 – 1500	650 – 1400
Potassium	6000 – 10 000	/
Iron	5 – 25	20 – 45
Vitamin A	0 – 70	/
Vitamin C	380 – 900	120 – 190

(Source: Wheatley *et al.*, 2003)

2.2.6 Storage Methods of Fresh Cassava Roots

One major problem involved with the cassava root is its rapid physiological deterioration 2–5 days after harvest (Omafuvbe *et al.*, 2007; Wheatley *et al.*, 2003) followed by microbial deterioration 3–5 days later ((Rickard and Coursey, 1981). Cassava roots must be harvested and handled with extreme care if they are to be kept for a good number of days. The cassava root (which is the storage organ) deteriorating very rapidly has been attributed to the fact that it has no dormancy, has no function in propagation and possesses no bud primordia from which regrowth can occur (Cooke *et al.*, 1988a). It must therefore be processed immediately after harvest into different stable final products. Deterioration is also due to the rapid synthesis of simple phenolic compounds (catechins, coumarins, leucoanthocyanins) that polymerize to form blue, brown and black pigments (condensed tannins) (Wheatley *et al.*, 2003).

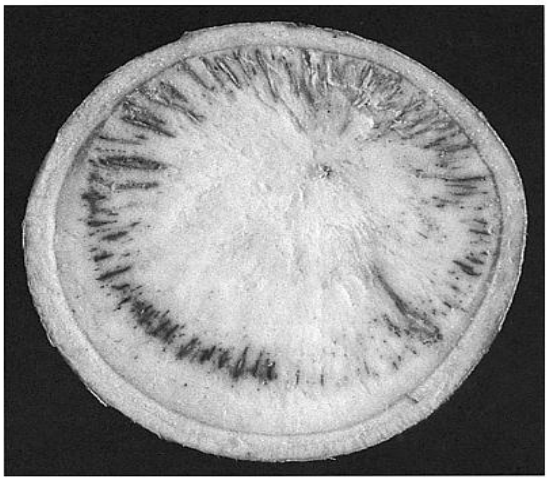

Figure 3: Transverse section through cassava root showing symptoms of physiological deterioration, three days after harvest. (Source: Wheatley *et al.*, 2003)

There are a number of different practices which, if applied, will assist in delaying cassava root deterioration. These include:

- Cutting off the stems, leaving only a short part above ground. This operation is done about three weeks prior to harvesting.
- As cassava roots usually start rotting from the neck, (i.e. the point of attachment of the root to the parent plant), harvesting the roots with part of the stem (2–5 cm) still attached may prevent a rapid spread of decay into the root.
- Minimizing damage at lifting by harvesting while the soil is wet, for example after a rain.

- Retaining only those roots that do not show signs of injury. Roots that are to be kept for a week or more should be carefully selected since curing will not be effective on roots with extensive damage.

Traditional storage methods (Wheatley *et al.*, 2003) usually involve

- re-burying the roots in trenches covered with plant material and then soil;
- piling the roots in heaps and keeping them moist by watering them daily;
- applying a thick coating of soft clay or mud on washed roots;

Improved low-cost storage methods (Wheatley *et al.*, 2003) include:

- storage in boxes lined with moist sawdust or wood shavings,
- storage in plastic bags or plastic film wraps,
- using field clamp.

Improved higher cost techniques are those involving refrigeration, deep-freezing, waxing, controlled atmosphere and chemical treatments. Freezing and waxing have been used primarily for export markets in Europe and America where customers are prepared to pay high prices. These techniques require specialized equipment and skills and are very capital-intensive.

With all these storage methods, root quality is maintained for 2–3 weeks. Beyond this time, starch breakdown to free sugars gives roots an unacceptable sweet taste (Wheatley *et al.*, 2003).

2.2.7 Uses of Cassava (roots and leaves)

Cassava roots have both food and non-food uses. Cassava serves as a raw material for more than eighty industrial products worldwide (Elise and Dapeng, 2012), mostly employed in such industries as cassava starch for the production of natural adhesives, corrugated cardboard, gum remoistening, foundry, well drilling, paper industry, textile industry, biofuel, stain remover, detergents, alcohol, acetone, etc. (Babajide and Olowe, 2013; Kuiper *et al.*, 2007). Good quality silage can be obtained from fresh cassava peels (Heuzé *et al.*, 2013).

Cassava roots can be transformed into a good number of food products (Lasekan *et al.*, 2004). These include **fufu** ("**water-fufu"), gari**, **cassava flour**, **bread, "bobolo**" (**baton),** dried cassava chips, "**miondo**", **mitoumba**, etc. Cassava flour improper for human consumption is recycled as animal feed. The roots can be peeled and boiled, mashed, roasted or even deep-fried for human consumption (Heuzé *et al.*, 2012).

Gari ("tapioca") is obtained by grating fresh cassava roots and fermenting them for 2 – 4 days, then dewatering, sieving, frying (Enidiok *et al.*, 2008) and finally cooling the fried product which may or may not be re-sieved. Small quantities of palm oil may be added during the frying stage in order to obtain yellow gari. Gari is a convenience food with a short preparation time. Its cheapness, ease of storage and preparation for consumption has combined to make it extremely popular among the urban dwellers in West and Central African countries (Irtwange and Achimba, 2009). It is a granulated product that has a long shelf life and is in a ready-to-eat form (Cardoso *et al.*, 2005). Gari is the most popular cassava food product in Africa and can be eaten dry or with cold water or reconstituted with hot water to form a "dough" which is eaten with soups (Oyewole *et al.*, 2004).

"**Bobolo**": This is made by fermenting fresh cassava roots in water for duration of time and the resulting soft pulp is defibered and ground to form a paste. The paste is wrapped in plantain leaves or other convenient leaves and cooked to give the final product.

Cassava flour: Fresh cassava roots are harvested and peeled, washed, cut into small sizes (4 – 5 mm) and then sun-dried ((Djilemo, 2007) by spreading on open cloths, large, black polythene sacs, or zinc pieces until all the water is totally evaporated. The resulting dried chips are then milled into cassava flour, sieved and stored in polythene bags to be used when need arises such as in the production of fufu. Non-fermented high quality cassava flour (without odour, having white colour and homogenous granulometry) can be used as a raw material for the production of bread, "gateau", biscuits and others.

Fufu, which is also called "Akpu" in Nigeria and in a few parts in Cameroon, is a fermented wet paste from cassava (Oyewole and Sanni, 1995). It is prepared traditionally by peeling the cassava roots, washing, cutting into smaller pieces and steeping in water for 3–5 days or more. Fermentation processes help to detoxify the cassava pulp; help in preservation and in flavour development (Hahn, 1989). The fufu is slurried in water, cooked with continuous stirring to produce stiff elastic dough eaten with soups or stews. Details of fufu preparation vary from locality to locality (Sanni *et al.*, 2006). It has been noted that fufu supplies calories needed for rural life more adequately than most cassava products (IITA, 1990). Among fermented cassava products, fufu is unique because in the traditional processi ng, the product is not subjected to any other processing after fermentation before cooking

a b c

Figure 4 : Pictures of some cassava root products: (a) "bobolo", (b) yellow gari, (c) cooked "water-fufu"

Other cassava products (apart from the root) include the finger-like leaves which are consumed as vegetables or used as feed. Unlike the roots, cassava leaves are a rich source of proteins consumed in Africa and elsewhere (Bradbury, 2006). However, the leaves are not widely used as a food source despite their high protein content. This is attributed to the fact that the leaves contain a great portion of linamarin (95% of cyanogenic glucoside). More than a third of cassava production in the world is used for animal feeding (FAO, 2011)

Table 3. The main processing areas of some cassava root products in Cameroon

Product	Gari	Waterfufu	Fufu
Main Areas	Malendé (Muyuka) Muyuka Oyé Passim (Melong) Balengui (Kumba	Batoke et Bakinguili (Limbe) Lelem (Melon) Sollé (Yabassi) Malende (Muyuka) Malende (Kumba) Ikiliwindi	Baré (Nkongsamba) Melong II Sollé (Yabassi)

Source: PNDRT, 2010

Cassava is an excellent source of carbohydrate the main carbohydrate which is contained in the cassava is starch.

2.3 Starch

Utilisation of any crop as an industrial raw material depends on a number of factors such as growing conditions, availability, price and ease of use (Jarowenko, 1977). In many cases, availability becomes the determining factor since this affects the price (Moore et al., 1984; Fabiano et al., 2001). This explains why the USA uses maize starch, Canadians, Australians and New Zealanders use mostly wheat starch, while Europeans use potato and maize starch. Tropical countries like Brazil Cameroon and the East Indies (in Asia) use cassava starch (Radley, 1976; Jarowenko, 1977; Wurzburg, 1986a). Cassava has the highest starch content among root and tuber crops (Moorthy, 1994). Cassava starch extraction is easy since it settles rapidly and gives a good yield. The resulting starch is free from any colour or impurities, in contrast to other plant starches which are contaminated with proteins or fats and are hence discoloured (Moorthy, 1994). Cassava can be useful for the production of starch because it is high yielding and gives high return per unit energy input into cultivation (Agboola et al., 1990; Rickard et al., 1991). Starch is a valuable ingredient for the food industry, being widely used as a thickener, gelling,bulking and water retention agents (Niba *et al.*, 2001; Singh *et al.*, 2003). Cassava starch is used directly in different ways or as a raw material for further processing in the production of paper, textiles, as monosodium glutamate (MSG), and as an important flavouring agent in Asian cooking (FAO, 2001; IITA, 2001; Benesi, 2002). Cassava starch use has a high potential for growth, both in industry and for human consumption. The unique properties of cassava starch suggest its use even for speciality markets such as adhesives, baby foods, non-allergenic products and food for hospitalised persons (Moorthy, 1994; Thomas and Atwell, 1999; Masumbu, 2002). Starch is the most abundant reserve for carbohydrate in plants (Singh *et al.*, 2005). Moorthy (2001) pointed out that starch functional properties such as viscosity, gelatinisation temperature, and solubility need to be given attention. Numfor and Walter (1996) considered amylose content, average granule diameter, solubility and swelling power, enthalpy of gelatinisation (ΔHG) and profile texture as important starch functional properties. These insights on pasting and granular characteristics are relevant in quality assessment of cassava starch-based products and processing variables. Production of cassava starch in Cameroon would promote cassava production since more cassava will be needed for consumption whereas for starch production. Native and modified starches can be used to influence physical properties of many foods liken gelling, thickening, adhesion, moisture retention, stabilizing, and texturizing applications (Thomas and Atwell,

1999). Starch and its products are important in the paper, pharmaceutical, wood, packaging and textile industries, in ethanol and alcohol production, battery making, and in the production of explosives like matches (Whistler, 1984; Moorthy, 1994; Benesi et al., 2004).

2.3.1 Composition of Starch

Starch, which exist as a granule are semi crystalline aggregates. The diameters of starch granules generally range from 1µm to more than 100µm, and shapes can be regular (spherical, ovoid or angular) or quite irregular. The diameter for cassava starch granules ranges from 4-35µm (Onwueme, 1978; Moorthy, 1994; Thomas and Atwell, 1999). The study of Moorthy and Ramanujam (1986) revealed that cassava starch granules increase in size two to six months after planting, then remain steady for the rest of the growing cycle of the plant. Cassava starch granules are mostly round or oval with a flat surface on one side containing a conical pit which extends into a well (Moorthy, 1994; Thomas and Atwell, 1999) Moorthy (1994) described it as an eccentric hilum, while Thomas and Atwell (1999) described it as truncated or kettledrum. Some granules appear perfectly round (Moorthy, 1994; Thomas and Atwell, 1999). Although the major components of all types of starch granules are amylose and amylopectin polymers, there is great diversity in the structure and characteristics of native starch granules depending on environment and source in terms of the biochemistry of the chloroplast or amyloplast and the physiology of the plant, as shown (Snyder, 1984; Thomas and Atwell, 1999; Singh and al., 2005).

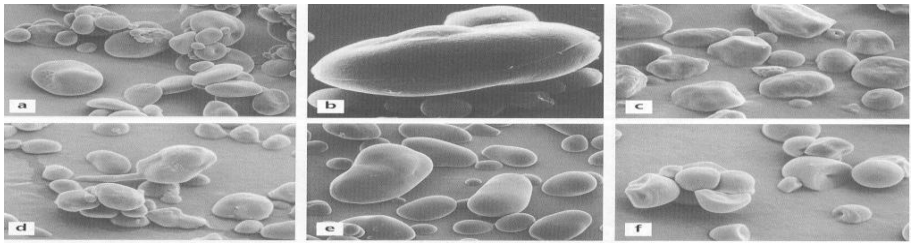

Figure.5 Scanning electron micrographs of starches from: (a) wheat (1000x); (b) wheat (2000x); (c) dent maize (2000x); (d) high-amylose maize (2000x); (e) potato (600x); and (f) cassava (2000x) (Evers, 1971; Thomas and Atwell, 1999)

2.3.1.1 Amylose

Amylose is essentially a linear polymer in which the glucose units are predominantly linked through α-1, 4 glucosidic bonds. Amylose content varies considerably among starches and genetic modifications have been done to obtain amylose content varying from 0-75% and part of it can exist as soluble amylose in the amorphous region of the starch granules (Moorthy, 2002). The molecular weight (MW) for amylose ranges between 243000µ and 972000µ. Although amylose from potato starch has been reported to have a MW of up to 1000000µ, the MW for amylose is typically less than 500000µ (Thomas and Atwell, 1999). The average MW of amylose from cassava starch seems to vary greatly, possibly due to the variety of cassava from which starch is extracted and extraction methods. For instance, three MWs of 232000µ (Ciacco and D'Applonia, 1977), 431000µ (Takeda *et al.*, 1984) and 522000µ (Suzuki *et al.*, 1985) for cassava amylose have been reported in literature. The average degree of polymerisation is 960 for maize, 3280 for cassava, 2000 for potato and 2600 for sweetpotato (Jarowenko, 1977; Takeda *et al.*, 1984; Wurzburg, 1986b).

Maize and wheat starch have an average amylose content of 28% and 26%, respectively, while potato, sweet potato and cassava have 20%, 18% and 17%, respectively (Onwueme, 1978; Young, 1984).

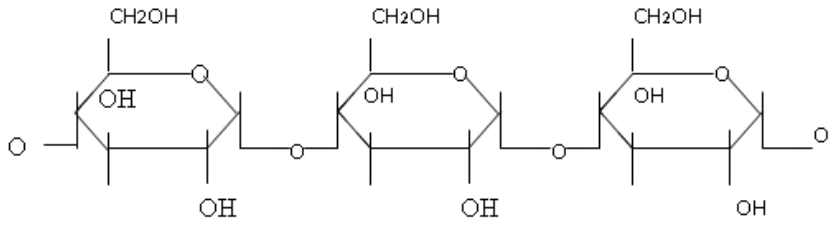

Fig.6 Chemical Structure of Amylose

2.3.1.2 Amylopectin

Amylopectin, like amylose, is a polymer with α-1, 4 glucosidic bonds. However, unlike amylose, it has periodic branches linked to C6 by α-1, 6 glucosidic bonds. The MW of amylopectin ranges from 10 million to 500 million (Thomas and Atwell, 1999). The relatively high amylopectin content of cassava probably accounts for the high MW. The average degree of polymerisation of amylopectin is 1450 for maize, 1300 for cassava and 2000 for potato (Jarowenko, 1977; Wurzburg, 1986a).

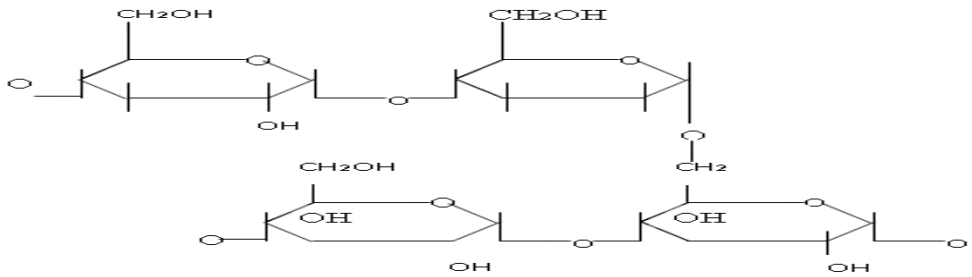

Fig.7 Chemical structure of Amylopectin

2.4 Physicochemical and functional properties of cassava starch

This includes swelling power, water-binding capacity, gelatinization, viscosity, solubility etc. This determines the quality of any starch and flour as well as its final usage.

2.4.1 Swelling power

This occurs as a result of increase in temperature of aqueous suspension above gelatinization temperature range. When this occurs, inter and intra molecular hydrogen bonds become disrupted giving way for water molecules to get attached to the liberated hydroxyl groups. It provides evidence for non-covalent bonds between starch molecules. Factors like amylose and amylopectin ratio, chain length and molecular weight distribution, degree or length of branching and conformation (Rickard et al., 1991) are related to swelling power. The swelling power of cassava is between those of potato and cereal starches (Moorthy, 2002). Asaoka et al., (1992) found in the work involving some cassava genotypes that swelling power was higher in the dry season than in wet season.

2.7.2 Solubility

It is defined as a solute ability to dissolve in solvent. This occurs when the adhesive force between the solute and the solvent becomes greater than the cohesive force between the solute molecules. It depends on a number of factors such as source, inter associative force, swelling power, presence of other components etc (Moorthy, 2002).Cassava starch has higher solubility than the other root crop starches and the higher solubility may be attributed partly to the high swelling cassava starch undergoes during gelatinization (Moorthy, 2002). Even though solubility values reported for cassava starch range from 25-48 %, Moorthy, (2001) observed a range of 17.2 – 27.2 % and found no direct correlation between swelling power and solubility.

2.7.3 Water – binding capacity

Water – binding capacity measures the water holding capacity of starch granules at room temperature. It is related to the viscosity of the starch and thus it is important in determining the bulking and consistency of products as well as in baking applications (Niba et al., 2001). This makes it important in determining starch use in products like sauces.

CHAPTER 3

MATERIAL AND METHODES

3.1- MATERIALS

To attempt are objective the following materials were used

3.1.1- BIOLOGICAL MATERIALS

- **Cassava**

The cassava chips (*Manihot esculenta* Crantz) used in this study were of different varieties from Chad, and Cameroon (South- West, East, south and Western region).

3.1.2- PREPARATION AND STORAGE OF CASSAVA CHIPS

The cassava chips used in this study was pounded using a wooden mortar and pistle to reduce the size of the chips. It was then grind to obtain fine cassava powder using an electric milling machine. The fine cassava powder was then stored in polythene bags to be used for analysis.

3.2 - EXPERIMENTAL METHODS

The physicochemical and functional characterization of these cassava varieties consisted of; the determination of total starch, amylose and amylopectin content, total cyanide content and ash content. Whereas the functional characterization consisted of; determining the Water absorption capacity, the least gelation concentration and the pasting properties using the Rapid Visco-Analyser. Before all these analysis were done, the dry matter and moisture contents have been determined to permit the expression of results in dry matter base.

3.2.1. PHYSICO-CHEMICAL CHARACTERIZATION OF THE CASSAVA VARIETIES USED

3.2.1.1- Dry Matter and Water (moisture) contents

Dry matter of a sample is a total of all substances in the sample that do not volatilize under the desiccation conditions defined by the method used. The dry matter and moisture contents of the cassava roots were determined by the method put in place by the AOAC (1986).

- **Principle**

The method is based on the measure of the loss in matter after drying at 105°C for a time period of 24 hours.

- Procedure

2g of cassava powder was weighed using electronic balance (Mark: Denver instrument, Model: APX-3202, max 3200, d=0.01g) and placed in a drying dish. The dish was then placed in a drying oven (mark: Heraeus, model: Kendro laboratory products, D-63450, Germany), previously set at 105°C and left there for 24 hours sufficient time to attained constant weight. After removal from the oven, the dish was cooled in a desiccator, and then weighed again. The dry matter content represents the difference in mass before and after drying in the oven. The procedure was repeated 3 times.

- **Expression of result**

The dry matter (DM) content in 100g of fresh sample was calculated using the following formula:

$$DM\ \% = \frac{M_2 - M_0}{M_1} \times 100 \qquad (1)$$

Where: M_0 = mass (in g) of empty drying dish, M_1 = mass (in g) of sample before drying, M_2 = mass (in g) of drying dish + sample after drying.

The water or moisture content (%W) was calculated using the following expression:

$$\%W = 100 - DM \qquad (2)$$

3.2.1.2- Determination Total starch and amylose content

The starch content was determined by the method described by Dicko (2006).

- **Principle**

Iodine (I_2) reacts with amylose and amylopectin to produce blue and brown colorations respectively. The absorption spectra of complexes of iodine-amylose and iodine-amylopectin are different. Because of this, these complexes have different maximal absorption wavelengths. However it is considered that maximal absorbance at 580 nm is due to both amylose and amylopectin. This can thus be used to measure the total starch in biological materials.

- **Procedure**

Preparation of the starch standard curve

0.5 g of starch was weighed with the aid of an electronic balance and dispersed in 20 ml of distilled water contained in a 100ml beaker. Into another beaker, 80 ml of distilled water was

pipetted and heated on an electric heater until boiling point. Then the 80ml of boiled distilled water was added to the 20ml containing 0.5g of starch. The mixture was then swirl lightly with our hands and left boiling for 5 minutes on the electric heater to obtain a turbid starch solution. The mixture was left to cool and using a measuring cylinder, the solution was completed to a volume of 100 ml with distilled water. This constituted a stock solution of starch at 5 mg/ml. The standardization curve was established as follows in (measurements were done in triplicate):

Preparation of the amylose standard curve

0.5 g of the amylose was weighed on an electronic balance, and introduced into a 100ml round bottom flask. The round bottom flask was then placed into a boiling water bath and left to heat for 2 hours 30minutes. Then the round bottom flask was removed from the water bath and the solution inside was transferred into a beaker. The solution was left to cool and this served as the amylose stock solution.

N.B: Amylose is insoluble in water for this reason, not all the amylose we used dissolved in solution. Hence in order to know the exact quantity that dissolved, the following was done:

The empty round bottom flask was weighed, and the mass recorded. After collecting the amylose solution that dissolved in the beaker, the round bottom flask containing non-dissolved amylose was weighed once more and the mass recorded. The round bottom flask was then place in an oven for 105°C. The round bottom flask was removed after 4 days; time estimated that the mass of non-dissolved amylose will be constant. The round bottom flask was once more weighed on an electronic balance. The following calculation was carried out to know the amount of amylose that actually dissolved:

Mass of empty round bottom flask:

Mass of empty round bottom flask + amylose residue:

Mass of dried ball + amylose residue:

- Mass of amylose placed in the oven = Mass of empty round bottom flask + amylose residue - Mass of empty round bottom flask.
- Mass of dried amylose residue = Mass of dried ball + amylose residue – Mass of empty round bottom flask.

Preparation of the sample

The dried cassava chip was pounded with the aid of a wooden mortar and pestle to reduce the particle size. It was then milled using a small electrical miller to obtain fine cassava powder. The cassava powder was then used as such for starch analysis.

0.1 g of the biological material (cassava powder and cassava starch) was weighed into a test tube and 5 ml of 1N KOH added. The mixture was homogenized at room temperature using a glass stirrer. After which each test tube was agitated using an electrical vortex for 30 seconds. The mixture was then neutralized with 5 ml of 1N HCl. The mixture was boiled in a water bath for 15 minutes and the volume adjusted to 10 ml. A blank solution was prepared using 0.05ml of distilled instead of the sample. The mixture of the samples was centrifuge at 3500 rpm for 20 minutes and the supernatant taken and used to measure starch as shown below.

MEASUREMENT OF TOTAL STARCH AND AMYLOSE CONTENT

Into 10 test tubes, the following volumes of the starch stock solution were introduced. After which, distilled water followed by iodine was introduced in the volumes indicated below. The solutions were then incubated for 10 minutes and read using a spectrophotometer at OD 580nm. The same was done for amylose but the solutions were read at 720nm.

Table Measurement of total starch

Reagent/Tube	**Blank**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**sample**
Starch (5 mg/ml) in ml	0.0	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.10	0
Water (ml)	4.9	4.89	4.88	4.87	4.86	4.85	4.84	4.83	4.82	4.81	4.8	4.85
I_2/KI (ml)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Incubate	10 minutes before reading optical density											
OD 580 nm												
Mean OD												

- **Expression of result**

The total starch in the sample is calculated as follows:

$$OD = m\ X\ + C$$

Where X = concentration of starch in sample, m = gradient and C is the Y intercept.

$$X = \frac{OD - C}{m}$$

$$\%\ starch = \frac{X \times V_T \times 100}{10^3 \times V_p \times M_s \times dm} \times 100$$

Where V_T = total volume of extract (5 ml), V_P = volume of specimen (0.05ml), M_S = mass of sample (0.1 g), dm = dry matter content of sample.

Table: Measurement of amylose

Reagent/Tube	**blank**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**sample**
Starch (5 mg/ml) in ml	0.0	0.02	0.04	0.06	0.08	0.1	0.12	0.14	0.16	0.18	0.20	0
Water (ml)	4.9	4.88	4.86	4.84	4.82	4.8	4.78	4.76	4.74	4.72	4.7	4.85
I_2/KI (ml)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Incubate	10 minutes before reading optical density											
OD 720 nm												
Mean OD												

3.2.1.3-Ash

The ash content of the flours was measured using the method described by the AACC (1999).

- **Principle**

Total ash is the residue of calcination of organic matter at 550°C. The principle consists of burning a sample previously dried in a muffle furnace until it attains a constant weight.

- **Procedure**

2,5g of the sample was placed into the ceramic ashing dishes that had been washed, dried, ignited and cooled in a desiccator, and weighed using an electronic balance (Mark: Denver instrument, Model: APX-3202, max 3200, d=0.01g) . The dish containing the flour was then placed in the muffle furnace set at 550°C and incinerated until light gray ash was obtained. The ashing dish was then cooled in a desiccator and weighed when room temperature was attained. The procedure was repeated 3 times for each of the cassava powder.

- **Expression of result**

Total ash per 100 g of flour was calculated as:

$$\%Ash = \frac{weight\ of\ residue}{weight\ of\ sample} \times 100$$

Where weight of residue = (weight of crucible + residue) – weight of empty crucible

3.2.1.4 -Determination of HCN in cassava

The HCN content was determined by the method put in place by Makkar et al.;(2007)

Principle

This method is based on the formation of potassium Cyanide and reaction with picrate

Procedure

Preparation of standardization curve

241 mg of KCN was dissolved in a flask of 1 L with some distilled water and then completed after dissolution to 1l with distilled water, which gives 100µg of HCN/mL. This solution was then diluted 4 times to have a concentration of 25µg of HCN/ml from which a standard curve was prepared in the range of 2.5 to 25µg equivalent of HCN.

Preparation of Sample

2g of cassava powder was mixed with 62.5 ml of distilled water. It was then allowed to stand for 4hrs followed by the addition of 1.25 ml of chloroform in a round bottom flask. It was then distillation, and HCN which result from it was trapped into a 50-ml test tube containing 2.5ml of 2% KOH. Approximately 10ml of the distillate was collected and the distillation stopped. This volume was then completed to 25ml with distilled water. 5-mL aliquot of the well-mixed distillate was introduced into a test tube and 5ml of alkaline picrate solution was added onto it . The content of the test tubes was well mixed and heated in a boiling water bath for 5min for color development. The color intensity was then measured at 520nm against the reagent blank (5 mL of distilled water and 5 mL of the alkaline picrate solution.) using a spectrophotometer (Mark: JENWAY, model: 7310, serial n^{o} 39756, United Kingdom).

Calculation

The total cyanide content of the sample was calculated by extrapolation from the calibration curve and taking into consideration the various dilution factors and the result express in milligrams per 1000 g of cassava powder sample on a dry matter basis.

3.3 FUNCTIONAL CHARATERIZATION OF CASSAV A VARIETIES USED

3.3.1-Least gelation concentration (LGC) of cassava

The LGC is a measure of the gelling ability of the flour. It provides structural matrix for holding water and other water soluble materials like sugars and flavours. It serves as a good binder or provides consistency in food preparations especially the semi-solid products Coffman and Garcia (1977)

Method

It was determined using the modified method of Coffman and Garcia (1977).A sample suspensions of 2% to 22 % (flour/water ratio) were prepared in different test tubes. The tubes containing the suspension were then heated in a gentle boiling water bath model for 1hour. After which the tubes were rapidly cooled. Each tube was then inverted one after the other. The LGC was taken as the concentration when the sample from the inverted test tube did not fall or slip

3.3.2

The water absorption capacity and solubility index in water at room temperature was determined by using the method described by Philip (1988) with some modifications.

Procedure

For determining the water absorption capacity and solubility index in water, 2 g of flour (M0) (with dry matter = DM) was mixed with 25 ml of distilled water, shaken for 2 minutes and allowed to stand for 15 minutes. The set up was then centrifuged at 6500 rpm for 10 minutes at room temperature using a centrifuge of (Mark: Heraeus-Kendro Lab products, model: Biofuge primo R, type: D-37520, Fab n^{o}: 284678, Germany. The wet sediment was weighed (M1) before being dried at 105°C for 24 hours and also weighed (M2). The procedure has been repeated 3 times for each of the flour.

- **Expression of result**

The real water absorption capacity (WAC_r) as well as the solubility index (SI) was calculated as follows at room temperature (g water/g flour

$$WAC_r = \frac{M1 - M0}{DM}$$

$$SI = \frac{M0 - DM}{M0} \times 100$$

3.3.3 - Pasting properties

The pasting properties were determined on flour suspensions of about 2.5 g flour (dry matter base) in 25 ml distilled water using a RVA (Perten instruments, Australia) with the following settings: initial temperature of 50°C which was held for 1 minute and then heating at the rate of 12.16°C/min to a temperature of 95°C. The temperature was then held for 2 minutes 30 seconds and then cooled to 50°C at the rate of 12.16°C/min and held for 2 minutes. The total test time was 13 minutes and the speed of the motor was 160 rpm. A summary of the treatment parameters is given in Table below. Pasting parameters were measured over time. The pasting parameters included Final viscosity (FV), Setback (SB), Breakdown (BD), Peak viscosity (PV) and pasting temperature.

Table: STD1 profile of RVA used for pasting properties

Stage	
Initial temperature, (°C)	50
Initial holding time, (minutes)	1
Heating time (minutes)	3 min 42 sec
Maximum temperature (°C)	95
Hold at max temp (minutes)	2 min 30 sec
Cooling time (minutes)	3 min 48 sec
Final temperature (°C)	50
Final holding time (minutes)	2
Total test time (minutes)	13

Source: Perten Instruments

Figure8: Rapid Visco- Analyser (Perten instruments)

This methodology has help us to obtain some results and also do some discussion as follows

CHAPTER 3

RESULTS AND DISCUSSION

Characterization of cassava roots allows us to classify them as a function of their toxicity and as a function of their physicochemical composition. To better appreciate the cassava variety used in this study, a characterization of it was carried out so as to come out with a functional and toxic cartography of these varieties and to be able to give a good comparison between cassava varieties from different localities. The results obtained are illustrated on the table as shown

TABLE 4: OF PHYSICOCHEMICAL PROPERTIES OF CASSAVA ROOTS ANALYSED THE RESULTS ARE EXPRESS AS A % OF DM

LOCATION	VARIETIES	TOTAL STARCH	AMYLOSE	AMYLOPECTIN	RATIO	HCN	ASH	DRY MATTER	MOITURE CONTENT
Mbama	Djangue(PR)	83.80±7.93 (efghijk)	15.35±1.74 (defghijkl)	84.65±1.74 (defghijklm)	0.18±0.02 (defghijklm)	39.16±2.64 (m)	1.55±0.00 (abcde)	88.50±0.00 (jklmno)	11.50±0.00 (bcdefg)
	Balbine(PR)	86.58±2.17 (hijk)	20.82±1.75 (o)	79.18±1.75 (a)	0.26±0.03 (pq)	36.64±3.09 (m)	2.03±0.16 (abcd)	88.50±1.00 (ghij)	11.50±1.00 (fhij)
	Mbout	86.36±8.73 (hijk)	15.82±1.16 (efghijkl)	84.18±1.16 (defghijkl)	0.19±0.02 (fghijklm)	32.80±1.58 (l)	2.00±0.87 (fgh)	85.33±2.25 (bcd)	14.67±2.25 (mno)
Ekondotiti	Batch4 8034	85.79±5.03 (hijk)	14.96±0.81 (cdefghi)	85.04±0.81 (fghijklmno)	0.18±0.01 (nop)	16.37±0.57 (b)	2.00±0.27 (bcdefg)	84.17±0.76 (hijklm)	15.83±0.76 (defghi)
	Vrac	86.79±0.90 (ijk)	19.04±0.33 (mno)	80.96±0.33 (abc)	0.24±0.00 (cdefghij)	17.45±0.65 (bc)	2.29±0.05 (fgh)	89.33±1.44 (nop)	10.67±1.44 (abc)

	Peau Jaune	**82.83±4.81**	**13.01±0.49**	**86.99±0.49**	**0.15±0.01**	**126.04±3.76**	**2.39±0.20**	**90.33±1.61**	**9.67±1.61**
		(fghijkl)	**(abcd)**	**(mnopq)**	(abcdef)	**(y)**	**(defgh)**	**(op)**	**(ab)**
	Poum–Poum	**80.95±0.45**	**12.56±0.53**	**87.44±0.53**	**0.14±0.01**	**20.00±0.90**	**2.31±0.05**	**90.50±1.41**	**9.50±1.41**
		(eighijk)	**(abc)**	**(nopq)**	(abcde)	**(cd)**	**(fghij)**	**(jklmno)**	**(bcdefg)**
Kamkoutou	**Nya**	**75.71±1.38**	**14.86±0.23**	**85.14±0.23**	**0.17±0.17**	**29.33±1.26**	**2.60±0.23**	**88.50±0.00**	**11.50±0.00**
		(bcdefg)	**(bcdefghi)**	**(efghijlmnop)**	(bcdefghijk)	**(ghij)**	**(fghi)**	**(jklmn)**	**(cdefg)**
	Madjinganem	**87.07±1.54**	**12.54±0.43**	**87.46±0.43**	**0.14±0.01**	**62.26±0.80**	**2.42±0.00**	**88.25±0.35**	**11.75±0.35**
		(ijk)	**(abc)**	**(nopq)**	(abcde)	**(u)**	**(cdefgh)**	**(fghijkl)**	**(defghij)**
	SIX Mois	**74.37±5.07**	**12.92±0.25**	**86.37±2.67**	**0.15±0.00**	**54.51±0.76**	**2.10±0.25**	**86.00±0.71**	**14.00±0.71**
	W	**(hijk)**	**(abcd)**	**(mnopq)**	(abcde)	**(s)**	**(defgh)**	**(fghijkl)**	**(efghijk)**

	Six Moisblanc V	87.50±0.46 (ijk)	12.34±0.51 (ab)	87.66±0.51 (opq)	0.14±0.01 (abc)	52.78±2.709 (s)	2.54±0.24 (hijk)	88.00±0.00 (ghijklm)	12.00±0.00 (defghij)
Daradja	Mbeguerel	90.52±6.12 (k)	17.65±1.61 (klmn)	82.35±1.61 (bcdef)	0.21±0.02 (lmno)	96.58±2.29 (x)	2.92±0.30 (fghi)	86.25±0.35 (fghijkl)	13.75±0.35 (efghijk)
	Six Mois Brun CC	83.84±8.00 (abc)	21.60±0.74 (lmn)	78.40±0.74 (bcd)	0.22±0.01 (q)	24.77±0.76 (e)	3.46±1.50 (hijk)	87.17±3.21 (bcdef)	12.83±3.21 (klmno)
	TME	87.57±1.89 (ijk)	12.15±0.65 (a)	87.85±0.65 (pq)	0.14±0.01 (ab)	86.03±0.57 (w)	2.30±0.68 (cdefgh)	82.50±0.00 (ghijklm)	17.50±0.00 (defghij)
Mboura	Gana	83.92±6.79 (efghijk)	12.13±0.85 (a)	87.87±0.85 (pq)	0.14±0.01 (ab)	46.33±0.78 (op)	2.73±0.00 (cdefgh)	87.00±0.50 (efghi)	13.00±0.50 (hijklm)
	Six mois U	86.44±3.07 (bcde)	17.05±1.96 (hijklmn)	87.08±0.25 (bcdefg)	0.21±0.03 (jklmno)	26.90±1.83 (efgh)	2.29±0.03 (fghij)	87.33±1.04 (ijklmn)	12.33±0.76 (cdefgh)

	Madjikouss X	**75.54±0.70** (bcdef)	**16.68±0.06** (hijklm)	**82.95±1.96** (lmnopq)	**0.14±0.01** (ab)	**18.78±0.21** (bcd)	**2.69±0.39** (klmn)	**86.75±0.35** (ghijklm)	**13.25±0.35** (defghij)
Berekouh	**Baga T**	**90.85±3.09** (k)	**13.08±0.23** (abcd)	**88.42±2.35** (q)	**0.13±0.03** (a)	**77.52±3.85** (v)	**2.16±0.46** (cdefgh)	**86.17±1.44** (ijklm)	**13.83±.44** (bcdefgh)
	BEREKOUH	**79.85±1.68** (cdefghij)	**12.48±1.18** (ab)	**87.52±1.18** (hijklmnopq)	**0.14±0.02** (abcd)	**59.04±1.73** (t)	**2.73±0.00** (cdefgh)	**88.00±0.00** (ghijklm)	**12.00±0.00** (defghij)
SOUTH	**Moic du sud**	**88.45±1.83** (bcde)	**13.87±0.19** (abcdefg)	**86.13±0.19** (nopq)	**0.16±0.00** (abcdefghi)	**47.62±0.47** (pq)	**2.29±0.26** (fghij)	**87.25±1.06** (fghijkl)	**12.75±1.06** (efghijk)
	96-14-14	**74.11±5.01** (ijk)	**16.15±2.45** (efghijkl)	**83.85±2.45** (cdefghijk)	**0.19±0.03** (ghijklm)	**46.70±1.46** (opq)	**2.58±0.29** (ghij)	**88.50±3.04** (p)	**11.50±0.04** (a)
	TMS 3001 Rouge claire L	**76.99±1.96** (bcdef)	**15.16±1.26** (defghij)	**84.84±1.26** (defghijklm)	**0.18±0.02** (efghijk)	**9.31±0.85** (a)	**3.17±0.83** (efghi)	**87.00±0.71** (jklmop)	**13 .00±0.71** (abcdefg)

	TMS 4(2) 1423 blanc A	70.31±0.12 (abcde)	13.89±0.04 (abcdefg)	86.12±0.04 (hijklmnopq)	0.16±0.00	28.30±2.69 (fghi)	2.33±0.11 (fghi)	89.25±1.06 (jklmnop)	10.75±1.06 (abcdefg)
	TMS 633397 Blanc B	86.99±1.60 (cdefghij)	14.66±2.03 (bcdefgh)	85.34±2.03 (ghijklmnop)	0.17±0.03 (bcdefghij)	44.11±0.72 (no)	3.48±1.44 (p)	89.17±0.76 (klmno)	10.83±0.75 (bcdeg)
	TMS 3001(Rouge)C	71.08±0.41 (fghijk)	17.86±0.84 (o)	82.14±0.84 (a)	0.28±0.01 (mno)	52.17±0.40 (rs)	2.25±0.06 (lmnop)	84.75±3.18 (b)	15.25±3.18 (o)
FOREKE-DS CHANG	TMS 60444(Blanc) D	83.48±2.45 (fghijkl)	17.15±0.81 (ijklmn)	82.85±0.81 (cdefghij)	0.21±0.01 (jklmno)	20.39±1.99 (d)	2.95±0.27 (ijkl)	84.67±0.29 (bcd)	15.33±0.29 (mno)
	TMS 633397 Blanc E	77.69±0.79 (bcdefghi)	17.60±0.24 (jklmn)	82.40±0.24 (bcdef)	0.21±0.00 (klmno)	46.19±1.44 (op)	2.24±1.49 (abc)	83.67±2.52 (cdefghij)	16.33±2.52 (jklmn)
	TMS 30572 Rouge F	74.98±0.24 (bcdef)	14.09±2.37 (abcdefg)	85.91±2.37 (ijklmnopq)	0.16±0.03	49.40±1.20 (qr)	2.20±0.59 (hij)	85.67±0.29 (defgh)	14.33±0.29 (ijklm)

	TMS 3001 Rouge claire G	**86.96±0.48 (bcdefgh)**	**16.40±0.34 (ghijklm)**	**83.60±0.34** (cdefgh)	**0.20±0.00** (hijklmn)	**32.87±1.33 (l)**	**3.18±0.86 (nop)**	**86.83±2.84 (lmnop)**	**13.17±2.84 (abcdg)**
FOTO-DSCHANG	**TMS 30572 HRougeFonce**	**65.07±10.08 (a)**	**13.65±0.61 (abcdef)**	**86.35±0.61 (jklmnopq)**	**0.16±0.11** (abcdefgh)	**36.77±1.25 (m)**	**3.64±0.53 (lm)**	**88.33±1.44 (ijklm)**	**11.67±1.44 (defgh)**
	TMS 4(2) 1423 blanc I	**71.68±2.47 (abcd)**	**15.03±0.57 (bcdefghijk)**	**84.97±0.57 (defghijklmnop)**	**0.18±0.01** (bcdefghijkl)	**32.19±0.94 (jkl)**	**3.52±0.22 (jkl)**	**87.33±1.26 (bcde)**	**12.67±1.26 (lmno)**
	TMS 633397 Blanc J	**79.70±0.10 (bcefg)**	**19.20±0.51 (no)**	**80.80±0.51 (ab)**	**0.24±0.01** (op)	**29.70±0.73 (hij)**	**3.05±0.14 (hij)**	**83.33±0.29 (bcd)**	**16.67±0.29 (mno)**
	TMS 50595 K	**73.34±0.34 (bcdefgh)**	**16.55±0.21 (hijkl)**	**83.45±0.21 (cdefgh)**	**0.20±0.00** (jklm)	**30.07±1.08 (ijk)**	**2.58±0.28 (cdefgh)**	**86.17±3.33 (mnop)**	**13.83±3.33 (abcd)**

FONGO-NDENG DSCHANG	TMS 50595 Rouge claire L	72.83±2.56 (ab)	14.45±0.62 (abcdefghi)	85.55±0.62 (ghijklmnopq)	0.17±0.01 (abcdeghij)	42.72±0.81 (n)	2.48±0.44 (ijkl)	89.00±0.00	11.50±0.00 (cdefg)
	TMS 633397 Blanc M	79.61±0.23 (ijk)	16.55±0.23 (ghijklm)	83.45±0.23 (bcdhi)	0.20±0.00 (ijklmn)	20.05±1.06 (cd)	2.52±0.94 (a)	88.00±1.00 (ghijk)	12.00±1.00 (efhij)
	TMS 633397 N	76.60±3.73 (cdefghij)	13.33±0.87 (abcd)	86.67±0.87 (mnopq)	0.15±0.01 (abcdef)	46.01±0.95 (op)	1.70±0.66 (fghij)	85.50±2.65 (bcd)	14.50±2.66 (mno)
	TMS 30572 Rouge Fonce O	73.99±8.88 (defghij)	17.77±0.29 (lmn)	82.23±0.29 (bcde)	0.22±0.00 (mno)	32.76±0.44 (kl)	3.35±0.78 (mno)	84.33±1.44 (bc)	15.67±1.44 (no)
SANTCHOU-DSCHANG	TMS 3001(Rouge claire)P	85.13±1.54 (ghijk)	12.86±0.96 (abcd)	87.14±0.96 (nopq)	0.15±0.01 (abcde)	26.38±1.64 efg)	3.10±1.33 (ab)	83.67±1.53 (cdefghij)	16.33±1.53 (jklmn)
	TMS 60444(Blanc)Q	89.95±1.28 (jk)	13.46±3.31 (abcde)	86.54±3.31 (klmnopq)	0.16±0.04 (abcdefg)	17.90±0.58 (bcd)	2.31±1.63 (op)	83.83±2.08 (a)	16.17±2.08 (p)

	TMS 3001 Rouge claire R	**75.42±4.33 (ijk)**	**16.06±0.30 (efghijkl)**	**83.94±0.30 (defghijk)**	**0.19±0.00** (ghijklm)	**24.12±1.27 (e)**	**3.56±0.82 (hij)**	**80.83±8.50 (lmnop)**	**19.17±8.10 (abcdg)**
F0TESA-DSHANG									
	TMS 4(2) 1423 blanc S	**75.33±1.27 (a)**	**14.64±0.17 (abcdefghi)**	**85.36±0.17 (ghijklmnop)**	**0.17±0.00** (bcdefghij)	**9.36±0.83 (a)**	**2.37±0.44 (cdef)**	**89.17±1.04 (lmnop)**	**10.83±1.04 (abcdg)**
	TMS 30572 Rouge FonceXX	**80.61±0.41 (bcde)**	**15.99±3.60 (fghijkl)**	**84.01±3.60 (defghijk)**	**0.19±0.05** (ghjiklm)	**26.04±1.99 (ef)**	**2.14±0.22 (efgh)**	**88.33±1.26 (efghi)**	**11.67±1.26 (hijklm)**

Values are means of triplicates. Mean values having different superscript below the mean in bracket within column are significantly different ($P < 0.05$).

From above table, The amylose content between these cassava varieties varied significantly ($p<0.05$) and falls in the range (12.13- 20.82)% with the variety Gana presenting the smallest value 12.13±0.85 and the variety Balbine (PR) which presents the highest value of 20.82±1.75% when compared with all other cassava varieties used in this characterization. Hoover R (2001) found values varying from 18.6 to 25.6% for cassava starch depending on the plant variety. In another study, Aryee et al.; (2006) reported amylose content of 10.9–44.3% from roots of 31 cassava varieties. On a comparative basis, most of the samples analysed were lower than the range of values (17 to 35%) reported by Mbofung et al. (2006), for six varieties of taro. The observed values are also lower than potato (20%) and corn (28 – 30%) starches (Lineback, 1984) .This suggest that the values obtained fell within the ranges reported from other studies. Also amylopectin content varied significantly ($p<0.05$) for the cassava chips varieties with Balbine presenting the smallest value of 79.18±1.75% and Gana having the highest value of 87.87±0.85%.Thus this property makes this variety excellent for cooking because high amylose content favours rapid swelling of the starch granules. This difference in the amylose and amylopectin content may be due to the differences in varieties and the methods of extraction. The amylose and amylopectin content plays and important role in the functionality of starch (FAO, 1998).However, the viscosity, the gelatinization temperature, the water absorption capacity are all due to the differences in the ratio of amylose- amylopectin (FAO, 1998 ; Davies, 2009). This thus plays an important role in the industrial applications of starch. However a high amylose content (greater than 20 g/100g DM) will reduces the swelling capacity of the starch (Mufumbo *et al.,* 2011; Nuwamanya *et al.,* 2009) while those with values less than (20 g/100g DM) have less affinity to retrogratation. (Boursier, 2006).According to Leach *et al.* (1969), starches having a ratio of amylose/amylopectin greater than 0.25 have a high affinity to retrogratation. From the results obtain, ratio of amylose/amylopectin for most of the cassava varieties were less than 0.25 except for variety

TMS 3001(Rouge) from FOREKE-DSCHANG and Balbine (PR) from MBAMA which had values of 0.26±0.03 and 0.28±0.01 thus having a high affinity to retrogratation

The dry matter and moisture content of the cassava roots varieties varied significantly ($p<0.05$) giving a range of (80.83-90.50) %DM. The variety TMS 3001 Rouge claire from F0TESA-DSHANG had the highest value of 90.50%DM and the variety poum-poum from KAMKOUTOU had the lowest value of 80.83 %DM.However, varieties with

higher dry matter (and lowest moisture content) these varieties would be suitable for prolonged root storage (Trèche et al., 1995). According to Meuser and Smolnik (1980), high dry matter of cassava roots could contribute to increase the yield and the texture of derivative product. The varieties with relatively high moisture content are not suitable for prolong storage but could be suitable sources of raw materials for alcohol, lactic bacteria, organic acid (lactic, acetic, and formic) and biofuel industries (FAO, 2008). They could also be used for humans and animals feeding, as they contain nutritional elements like fat, protein, carotenoid, minerals, vitamins A and C

The cyanide content of the cassava varieties varied significantly ($p<0.05$) giving a range of 9.31±0.85mg/kg for the variety TMS 3001 Rouge claire Longue fueilli from FOREKE-DSCHANG to 126.04±3.76mg/kg for the variety Peau jaune from Kamkoutou (Chad).The cassava varieties used in this study were, on the whole, sweet (cyanide <100mg/kg of DM) with only one bitter variety Peau jaune which a cyanide content of 126.04±3.76mg/kg of DM (cyanide > 100mg/kg of DM) thus making this variety toxic. Nevertheless, all of them might not be consumed crude, but after cooking or transformation into edible products to reduce cyanide content (Ampe et al., 1994; Desmazeaud, 1996; Assanvo, 2008).

The starch content of cassava varieties varied significantly ($p<0.05$) giving a range of 65.07% to 90.85% for TMS 30572 Rouge Foncer and Baga respectively. This variation in starch content may be due to it interaction with other constituents present in cassava such as fibers and lipids. The high value of 90.85±3.09% show a good extraction of starch whereas the low starch content of 65.07±10.08% which fall out of the range 70-91% DM reported from literature (Ernesto, 2002) may be due to the fack that the cassava variety was not the same as that used by (Ernesto, 2002) and so their starch content are not bound to be the same.

The ash content gives the total mineral content in cassava. The ash content of the cassava root varieties varied significantly ($p<0.05$) giving a range of (1.55-3.64%). The variety Djangue (PR) from Mbama had the lowest value of 1.55% whereas the variety TMS 30572 Rouge Fonce from FOTO-DSCHANG had the highest value of 3.64% for the variety. Most of the cassava varieties used in this study fell with the range of values reported in literature (1-2.5%) Alfredo, 2002 .This variation in ash content may be due to the fact that the cassava variety

was not the same as that used by(Alfredo, 2002) and so their ash content are not bound to be the same.

Table:5 functional properties of cassava varieties analyzed results are express as %dm

LOCATION	VARIETIES	LGC	WACR	S.I
MBAMA	Djangue(PR)		219.05±7.90 (fg)	17.67±0.58 (bc)
	Balbine(PR)		203.36±7.69 (de)	20.00±1.00 (bcdef)
	Mbout		295.41±15.97 (lmn)	21.33±3.79 (defghi)
EKODOTITI	Batch4 8034		184.77±6.65 (c)	21.33±0.58 (defghi)
	Vrac		293.10±20.11 (lmn)	27.67±5.03 (lm)
KAMKOUTOU	Peau Jaune		332.44±21.82 (o)	32.67±2.52 (mno)
	Poum -Poum		365.99±20.97 (p)	34.67±3.21 (o)
	Nya		295.36±8.67 (lmn)	34.00±1.41 (no)
	Madjinganem		287.09±2.76 (klm)	26.33±0.58 (klm)
	SIX Mois W		234.03±2.79 (fg)	21.50±0.71 (defg)
DARADJA	Six Moisblanc V		285.04±2.71 (klm)	22.00±1.00 (fghij)
	Mbeguerel		280.29±2.70 (jkl)	26.50±0.71 (klm)
	Six Mois Brun C		266.68±2.46 (hij)	23.50±0.71 (ghijkl)
MBOURA	TME		216.58±3.75 (ef)	21.50±0.71 (defg)
	Gana		262.11±3.35 (hi)	23.50±0.71 (ghijkl)
	Six mois U		188.36±4.34 (cd)	31.00±1.41 (mn)
	Madjikouss X		275.28±6.03 (ijk)	26.00±1.73 (lm)
BEREKOUH	Baga T		289.86±0.00 (klmn)	31.67±1.15 (mn)
	BEREKOUH		300.83±12.20 (mn)	24.50±2.12 (ijklm)
SOUTH	Moic du sud		305.17±3.09 (n)	32.50±0.71 (mno)
	96-14-14		292.49±3.18 (lmn)	21.33±0.58 (defghi)
	TMS 3001 Rouge claireLF		262.17±6.27 (hi)	29.50±1.41 (lm)

FOREKE-DSCHANG	TMS 4(2) 1423 blanc A	191.36±0.78 (cd)	12.83±0.76 (a)
	TMS 633397 Blanc B	183.03±0.78	31.83±1.04 (mno)
	TMS 3001(Rouge) CC	232.93±10.60 (g)	24.33±1.44 (jkl)
	TMS D 60444(Blanc)	195.41±0.02 (cd)	23.75±0.35 (hijkl)
	TMS 633397 Blanc E	189.77±6.70 (bc)	18.67±0.76 (bcd)
	TMS 30572 Rouge F	252.52±0.02 (h)	21.17±1.26 (defgh)
FOTO-DSCHANG	TMS 3001 Rouge claire G	143.27±1.71 (b)	11.00±0.50 (a)
	TMS 30572 Rouge Fonce H	256.36±0.86 (h)	17.33±0.29 (b)
	TMS 4(2) 1423 blanc I	148.28±1.36 (c)	18.50±1.32 (bcd)
	TMS 633397 Blanc J	187.70±3.43 (cd)	19.00±0.50 (bcde)
FONGO-NDENG DSCHANG	TMS 50595K	224.10±2.61 (fg)	10.75±0.35 (a)
	TMS 50595 Rouge claireL	196.00±12.85 (cd)	25.17±4.01 (klm)
	TMS 633397 Blanc M	188.39±1.65 (cd)	32.50±1.32 (mno)
	TMS 633397N	127.73±0.34 (a)	23.67±0.29 (hijkl)
	TMS 30572 Rouge Fonce O	187.22±3.75 (c)	20.50±1 .32 (cdefg)
SANTCHOU-DSCHANG	TMS 3001(Rouge claire) P	186.75±0.42 (c)	22.00±0.71 (efghijk)
	TMS 60444(Blanc) Q	194.06±1.37 (cd)	32.83±2.25 (no)

	TMS 3001 Rouge claireR	219.82±3.08 (fg)	23.67±1.26 (hijkl)
F0TESA-DSHANG	TMS 4(2) 1423 blancS	128.58±2.77 (a)	11.33±0.76 (a)
	TMS 30572 Rouge Fonce XX	257.02±6.82 (h)	22.50±1.80 (fghijk)

Values are means of triplicates. Mean values having different superscript below the mean in bracket within column are significantly different ($P < 0.05$).

The ability to absorb water is a very important property of all flours and cassava roots used in food preparations. The range of water absorption capacity (127.73±0.34–365.99±20.97) % observed for the different cassava varieties analysed showed that Poum –Poum from Kamkoutou had the highest value of 365.99±20.97%, while TMS 633397N from Fongo-ndeng dschang had the lowest 127.73±0.34% water absorption capacity. The cassava varieties were significantly different ($P < 0.05$) in their water absorption capacity. The ability of food materials to absorb water is sometimes attributed to its proteins content (Kinsella, 1976). The observed water absorption capacity of cassava studied cannot, however, be attributed to their protein content since cassava and cassava starch in particular is very poor in protein. The observed differences in water absorbed may have been due to the nature of the starch (Sathe and Salunkhe, 1981b). Increase in water absorption capacity in food systems enables bakers to manipulate the functional properties of dough in bakery products (Achinewhu and Orafun, 2000; Iwe and Onadipe, 2001). TMS 633397N from Fongo-ndeng dschang with the highest level of water absorption capacity will be useful in meeting the cassava initiative for the bread industry in Cameroon.It has been shown that the size of the granule influences the water absorption capacity. Infact Tian *et al.* (1991) suggested that granules of smaller sizes have a high affinity for water absorption capacity. This thus have an effect on the functionality of flour and starch. This variation in WAC among the different cassava varieties is due to the interaction of the hydroxyl groups to form hydrogen and covalent with the starch chains (Hoover & Sosulski, 1986).

The solubility index is the measure of the quantity of amylose that solubilized in an aqueous suspension of starch during heating. During heat treatment of starch, amylose diffuses out of the granule and solubilizes in an aqueous medium (Boursier, 2006).The solubility of starch is therefore a function of amylose content

Table 5: Pasting properties of cassava varieties

LOCATION	VARIETIES	Peak Viscosity (cp)	Holdviscosity (cp)	Final viscosty (cp)	Break down viscosity(cp)	Set Back (cp)	Pasting temperature (℃)
MBAMA	Djangue(PR)	2270±681^{h}	1233±3.70^{f}	1892±5.68^{e}	1037±3.11^{n}	659±1.98^{d}	71.17±0.21^{stu}
	Balbine(PR)	1597±4.76^{c}	1181±3.54^{d}	1870±5.61^{d}	416±1.25^{c}	689±2.07^{e}	50.26±0.15^{a}
	Mbout	2364±7.09^{h}	1450±4.35^{k}	2569±7.71^{s}	914±2.74^{k}	1119±3.36^{z}	72.21±0.22^{w}
EKODOTITI	Batch4 8034	2417±7.25 (c)	1396±4.19^{j}	2210±6.63^{i}	1021±3.06^{m}	814±2.44^{no}	72.65±0.22^{x}
	vrac	2522±7.57 (j)	1980±5.94^{za}	2885±8.66^{za}	542±1.83^{e}	905±2.75^{r}	71.22±0.21^{tu}
	Peau Jaune	3179±9.54 (k)	1182±3.55^{d}	2270±6.81^{j}	1997±5.99^{zh}	1088±3.26^{y}	70.57±0.21^{pqr}
	Poum -Poum	2677±8.03 (l)	1687±5.05^{r}	2477±7.43^{o}	990±2.97^{l}	790±2.37^{m}	71.45±0.21^{u}

KAMKOUTOU	Nya	3172±9.52^{yz}	1598±4.79^{n}	2408±7.22^{m}	1574±4.72^{zc}	810±2.43^{n}	50.93±0.15^{b}
	Madjinganem	2201±6.60^{c}	301±0.90^{a}	390±1.17^{a}	1900±5.70^{zg}	90±0.27^{a}	74.54±0.22^{y}
	SIX Mois W	2325±6.97 (d)	1658±4.97^{d}	2405±7.22^{f}	667±2.00^{f}	747±2.24^{k}	50.31±0.15^{a}
DARADJA	Six Mois blanc V	2653±7.96 (f)	1600±4.80^{n}	2533±7.60^{q}	1053±3.16^{o}	933±2.8^{t}	70.88±0.21^{rs}
	Mbeguerel	1483±4.45 (j)	582±1.75^{a}	784±2.35^{b}	901±2.7^{j}	202±0.61^{b}	50.36±0.15^{a}
	Six Mois Brun C	2717±8.15 (o)	1520±4.56^{l}	2341±7.02^{l}	1197±3.59^{w}	821±2.46^{o}	52.35±0.16^{d}
	TME	2444±7.33 (b)	1298±3.89^{h}	2021±6.06^{g}	1146±3.44^{s}	723±2.17^{h}	70.59±0.21^{qr}
		3260±9.78	1788±5.36^{u}	2626±7.88^{u}	1472±4.22^{y}	8380±25.14^{z}	51.29±0.15^{c}

MBOURA	Gana	(q)				c	
	Six mois U	1762±5.29^{xy}	1188±3.56^{p}	1956±5.87^{m}	574±1.72^{h}	768±2.30^{t}	70.87±0.21^{rs}
	Madjikouss X	3186±9.56^{z}	1317±3.95^{i}	2326±6.98^{k}	1869±5.61^{zf}	1009±3.03^{w}	70.44±0.21^{opq}
BEREKOUH	Baga T	1338±4.01^{zf}	1949±5.85^{y}	1711±5.13^{c}	179±0.50^{a}	552±1.66^{c}	50.31±0.15^{a}
	BEREKOUH	2197±6.59^{zc}	1539±4.62	384±1.15^{a}	1896±5.69^{zg}	86±0.26^{a}	70.54±0.21^{pq}
SOUTH	Moic du sud	1847±5.54 (r)	1740±5.22st	2119±6.36^{h}	641±1.92^{g}	913±2.74^{s}	50.3±0.15^{a}
	96-14-14	2536±7.61^{zd}	1671±5.01^{q}	2202±6.61^{i}	1093±3.28^{q}	759±2.28^{j}	53.71±0.16^{e}
			1159±3.48^{c}	2543±7.63^{qr}	2120±6.63^{zi}	1279±3.84^{zb}	67.77±0.20^{k}
FOREKE-DSCHANG	TMS 3001 Rouge claireLF	3384±10.15 (a)					

	TMS 4(2) 1423 blanc A	3016±9.05 (f)	297±0.89^{a}	2714±8.14^{x}	1153±3.46^{t}	851±2.55^{q}	70.2±0.21^{no}
	TMS 633397 Blanc B	2990±8.97 (e)	1206±3.62^{e}	2445±7.34^{n}	1253±3.76^{x}	708±2.12^{g}	69.3±0.21^{n}
	TMS 3001(Rouge) CC	2764±8.29 (m)	1443±4.33^{k}	2642±7.93^{v}	881±2.64^{i}	759±2.28^{u}	71.8±0.22^{v}
	TMS D 60444(Blanc)	3161±9.48^{ze}	1264±3.79^{g}	2547±7.64^{r}	1542±4.63^{zb}	928±2.78^{t}	67.7±0.20^{j}
	TMS 633397 Blanc E	2568±7.70^{v}	1863±5.59^{w}	2442±7.33^{n}	1166±3.50^{u}	1040±3.12^{x}	70.95±0.21st
	TMS 30572 Rouge F	3076±9.23 (u)	1737±5.21^{s}	2814±8.44^{z}	1104±3.31^{r}	842±2.53^{p}	70.15±0.21^{no}
FOTO-DSCHANG	TMS 3001 Rouge claire G	2730±8.19 (r)	1883±5.65^{x}	3212±9.64^{zf}	375±1.13^{b}	857±2.27^{q}	70.15±0.21^{no}
	TMS 30572 Rouge Fonce H	3252±9.76^{x}	1619±4.86^{o}	3082±9.25^{zd}	1165±3.49^{u}	995±2.99^{v}	66.9±0.20^{i}
FOTO-DSCHANG	TMS 4(2) 1423 blanc I	3453±10.36 (n)	1402±4.21^{j}	2928±8.78^{zb}	1256±3.77^{x}	731±2.19^{i}	70.25±0.21^{nop}
	TMS 633397 Blanc J	3797±11.39^{w}	1972±5.92^{z}	3128±9.38 ^{zd}	1665±4.99^{zd}	996±2.99^{v}	63.4±0.19^{f}
	TMS 50595K	2243±6.73 (q)	2355±7.07^{zh}	2583±7.75^{t}	496±1.49^{d}	836±2.51^{p}	70.15±0.21^{no}
	TMS 50595	2976±8.93^{xb}	2087±6.26^{zc}	2794±8.38^{y}	1773±3.52^{v}	991±2.97^{v}	69.45±0.21

FONGO-NDENG DSCHANG	Rouge claireL						
	TMS 633397 Blanc M	3237±9.71^{zg}	2197±6.59^{zf}	3047±9.14^{zc}	1088±3.26^{q}	898±2.69^{r}	66±0.20^{h}
	TMS 633397N	3312±9.94^{zi}	2132±6.40^{zd}	3234±9.70^{zh}	1089±3.27^{q}	1011±3.03^{w}	68.5±0.21^{l}
	TMS 30572 Rouge Fonce O	3556±10.67 (g)	1747±5.24^{t}	3190±9.57^{ze}	1531±4.59^{za}	1165±3.49^{za}	65.25±0.20^{g}
SANTCHOU-DSCHANG	TMS 3001(Rouge claire) P	2795±8.39 (t)	1803±5.41^{v}	2520±7.56^{p}	1055±3.16^{p}	780±2.34^{l}	67.75±0.20^{j}
	TMS 60444(Blanc) Q	3421±10.26^{za}	2149±6.45^{ze}	2676±8.03^{w}	1472±4.42^{y}	727±2.18^{hi}	67.7±0.20^{j}
F0TESA-DSHANG	TMS 3001 Rouge claireR	3321±9.96^{zc}	2223±6.67^{zg}	2536±7.61^{qr}	1482±4.45^{z}	697±2.09^{f}	66.9±0.20^{i}
	TMS 4(2) 1423 blancS	2762±8.29^{zh}	2025±6.08^{zb}	2519±7.56^{p}	1022±3.07^{m}	779±2.34^{l}	67.75±0.20^{j}
	TMS 30572 Rouge Fonce XX	3353±10.06 (s)	1740±5.22st	2643±7.93^{v}	1681±5.04^{ze}	972±2.92^{u}	70.1±0.21^{n}

Values are means of triplicates. Mean values having different superscript within column are significantly different ($P < 0.05$).

Table 6 shows the pasting properties of cassava roots

The peak viscosity, which is the maximum viscosity developed during or soon after the heating portion, ranged from (1338 to 3797) cP. Variety TMS 633397 Blanc from Foto-dschang gave the highest 3797cP while variety Baga from Berekouh gave the lowest value 1338 cP. There is significant difference in the peak viscosity of the cassava varieties ($P < 0.05$). This variation in the peak viscosity might be as a result of the amylose contents of the starches. Oguntunde (1987) reported that the associative bonding of the amylose fraction is responsible for the structure and pasting behaviour of starch granule. The viscosity or more correctly the consistency of a cooked starch paste simply reflects the resistance to stirring of the swollen mass gel particles. Peak viscosity has been reported to be closely associated with the degree of starch damage and high starch damage results in high peak viscosity (Sanni et al., 2001).

The results show that there were significant differences ($P < 0.05$) in the pasting temperature of the of cassava powder obtained from the different cassava varieties. Pasting temperatures of cassava roots ranged from 50.26°C for variety Balbine from Mbama to 70.95°C for variety TME from Mboura.The gelatinization temperature obtained was similar to the results for CMD resistant cassava 64.5 to 74.0°C (Omodamiro et al., 2007), chick pea 63.5 to 69.0°C and horse bean 50.4 to 70.0°C starches (Lineback and Ke,1975). The pasting temperature is one of the pasting properties which provide an indication of the minimum temperature required for sample cooking, energy cost involved and other components stability. It is clear from the results that the starch from variety Balbine will cook faster and less energy consumed, thereby saving cost and time compared to the other starch samples because of its lower pasting temperature. The wide variation in the pasting temperature among the cassava roots offered more opportunities for utilisation of cassava starches in several industries

The breakdown viscosity ranged from 416cP to 2120cP. TMS 3001 Rouge Claire longue feuilles from FOREKE-DSCHANG had the highest (2120)cP whereas variety Balbine from Mbama had the lowest value(416cP) .The values of breakdown viscosity of the cassava samples were significantly different ($P < 0.05$). Adebowale et al. (2005) reported that the higher the breakdown in viscosity, the lower the ability of the sample to withstand heating and shear stress during cooking. Hence, the starch sample from TMS 3001 Rouge Claire longue

feuilles from FOREKE-DSCHANG might be able to withstand heating and shear stress compared to starch sample from Balbin because of their low breakdown value.

The final viscosity ranged from 384cP to 3234Cp. Variety TMS 633397 had the highest (3234cP) final viscosity, while variety Berekouh had the lowest (384cp) final viscosity. These varieties were gotten from Fongo-ndeng dschang and Berekouh respectively. There is significant difference in the final viscosity of the cassava chips ($P < 0.05$). Shimelis et al. (2006) reported that final viscosity is used to indicate the ability of starch to form various paste or gel after cooling and that less stability of starch paste is commonly accompanied with high value of breakdown. This imply that starch paste from TMS 3001 Rouge Claire longue feuilles will be less stable after cooling compared to the other cultivars. The variation in the final viscosity might be due to the simple kinetic effect of cooling on viscosity and the re-association of starch molecules in the samples. The high final viscosities exhibited by TMS 633397 make them suitable in many food products such as sauces, soups, dressings and in the textile and the wet stage of paper making where high viscosities are desired (Moorthy, 2002), while the low final viscosities of Berekouh make them suitable for dried paper surface application where lower viscosity and good film forming capacity are preferred (Moorthy, 2002).

Results of the set back viscosity of the cassava roots samples ranged between 86 and 1279cp. with TMS3001 rouge claire longue feuille having the highest (1279cP) and that from Berekouh was the lowest (86cP). There is significant difference ($P < 0.05$) in the set back viscosity of the samples. Sanni et al. (2001) reported that lower set back viscosity during the cooling of *Gary* indicates higher resistance to retrogradation. This means that TMS3001 rouge claire longue feuille will exhibit higher resistance to retrogradation.

CONCLUSION

This work was aimed at characterizing the different cassava root varieties from their physicochemical, functional and pasting point of view so as to come out with a functional and toxic cartography of these varieties. Based on the physicochemical analysis it was observed that the different cassava roots had a concentration of cyanide less than 100mg/kg on a dry matter based, except for the variety Peau jaune which had a cyanide content of 126.04mg/kg of DM (cyanide > 100mg/kg of DM) thus making this variety toxic. Nevertheless, all of them might not be consumed crude, but after cooking or transformation into edible products to reduce cyanide content. All other physicochemical analysis (total starch, amylose, amylopectin, amylose/amylopectin ratio, cyanide, ash, dry matter and moisture content were observed to vary with cultivars. On the whole, the pasting and functional properties of cassava roots were observed to vary with cultivar. This characteristic is desirable for starch extracts to be used for the manufacture of value-added products such as noodles and composite blends with cereals. The pasting and functional properties obtained also indicate that the starches from these roots can be used in the food processing industry and non-food applications of starch such as in paper and textile industries.

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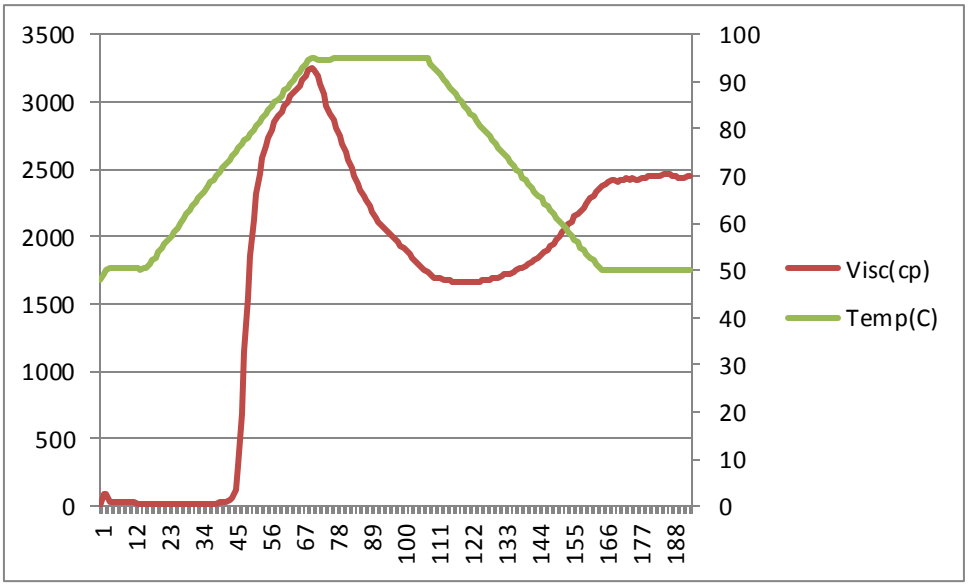
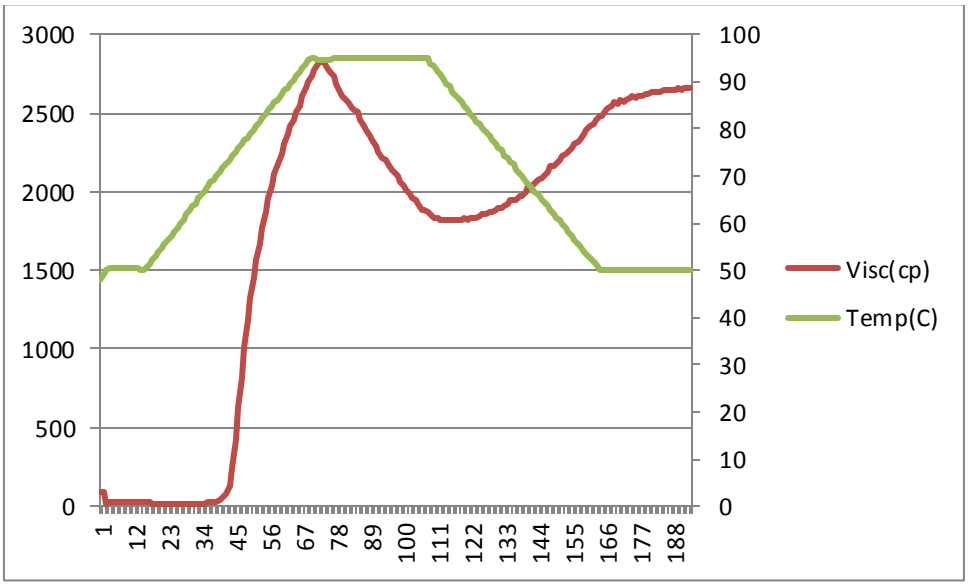
Appendix

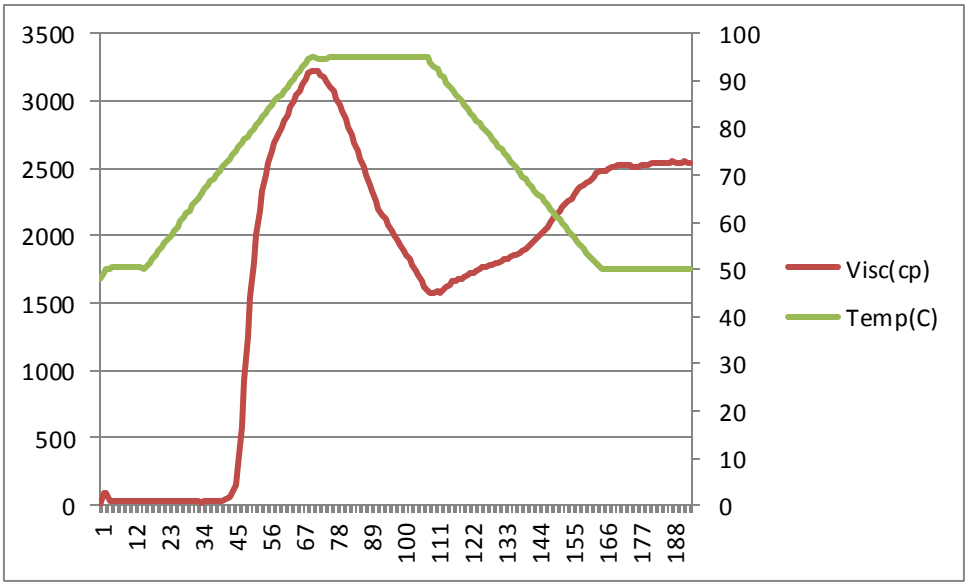
Appendix1: Graphs showing the variation of viscosity with temperature for some of the cassava roots



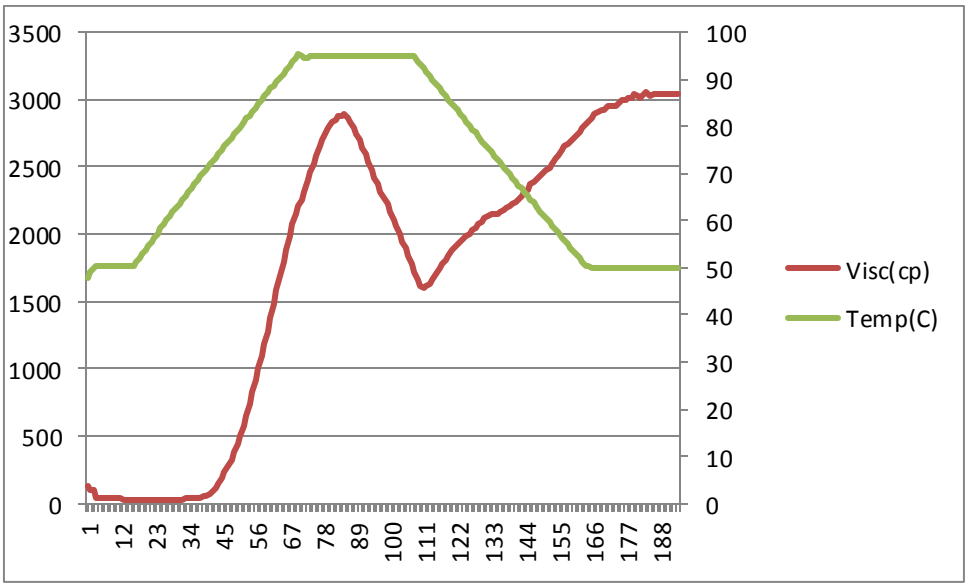
3=7



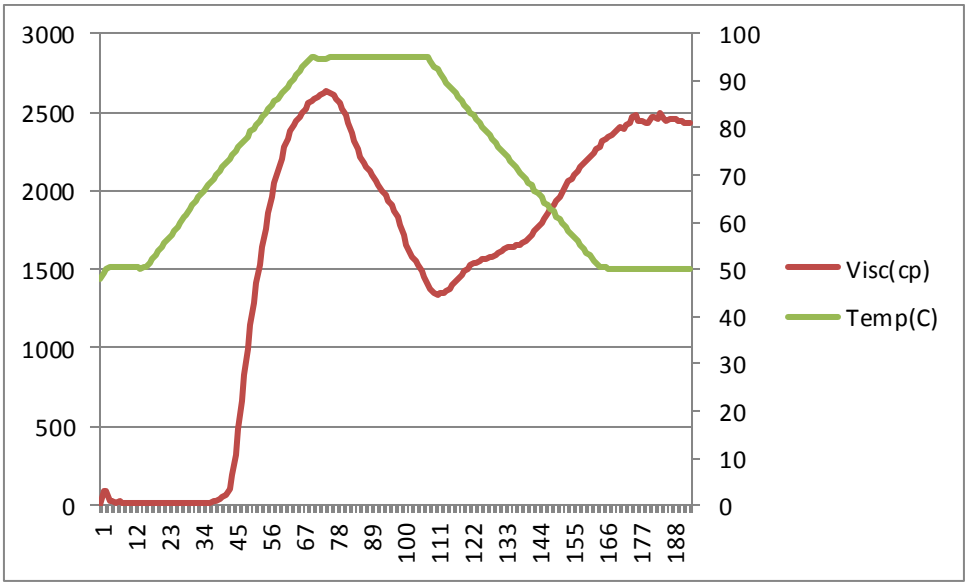
4=17


3500
3000
2500
2000
1500
1000
500
0
100
90
80
70
60
50
40
30
20
10
0
1
12
23
34
45
56
67
78
89
100
111
122
133
144
155
166
177
188
Visc(cp)
Temp(C)

34=5


3500
3000
2500
2000
1500
1000
500
0
100
90
80
70
60
50
40
30
20
10
0
1
12
23
34
45
56
67
78
89
100
111
122
133
144
155
166
177
188
Visc(cp)
Temp(C)

19=6



4=7

Appendix2: Standardization curves for Starch, amylose and HC

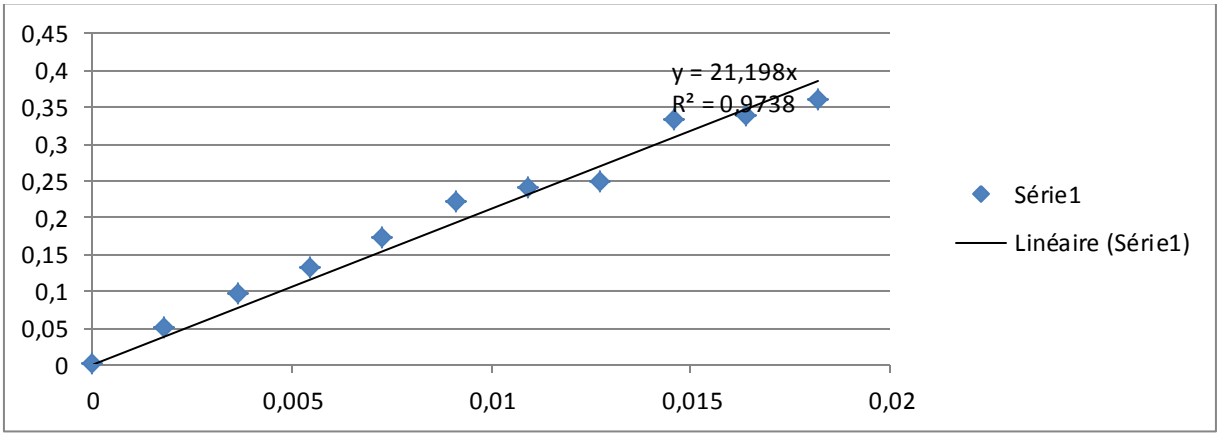


Fig 6: Standardization curve for amylose

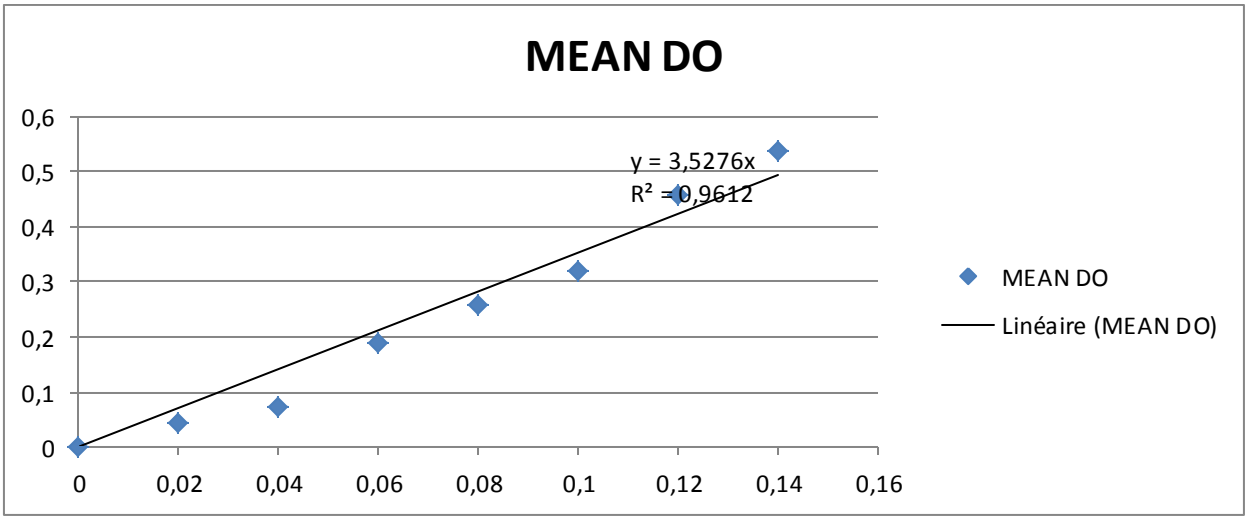


Fig:7 Standardization curve for Starch

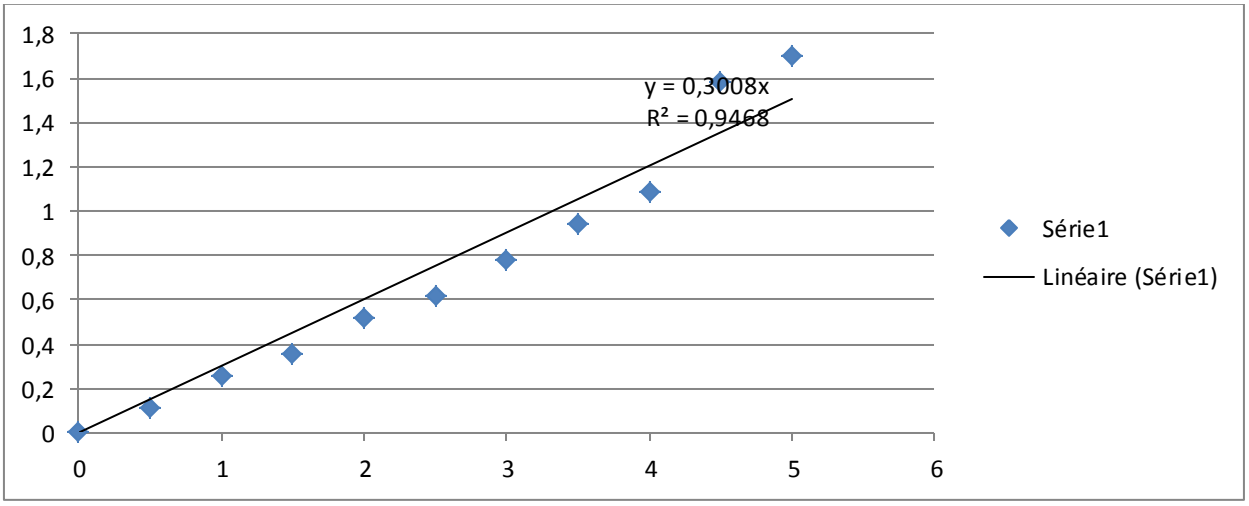


Fig :Standardization curve for HCN

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