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DEDICATION

TO THE ENTIRE ONGUENE AND OBONO'S FAMILY

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NEPAD: New Partnership for Africa's Development

IFAD: International Fund for Agricultural Development

PIDMA: Project for Investment and the Development of Agricultural Markets in Cameroon

IITA: International Institute of Tropical Agriculture

PGPA: Le Projet pour la Promotion des Groupements de Producteurs Agricoles

WECARD: West and Central African Council for Agricultural Research and Development

PNDRT: Programme National des Racines et Tubercules

PRASAC: Pôle Régional de Recherche Appliquée au développement des Systèmes Agricoles d'Afrique Centrale

ABSTRACT

Cassava starch is one of the products derived from cassava roots in Cameroon. Contrary to other cassava derived products, information with respect to; the uses, extraction process, producers, processing conditions, the market and the quality of the product, are not well known. Added to its weak position among other cassava derived products, the supply of cassava starch by local producers in Cameroon is believed not to respond to the market demand. The different users (agro-industries, the paper and card-board industry and dry cleaners) claim that the quantity and the quality of the product produced does not satisfy their requirements. In order to verify the stated hypothesis, this work had to come out with information on the cassava starch sector in the central region of Cameroon. Hence a survey coupled with the diagnosis of a given locality, was carried out in the central region of Cameroon. The survey helped revealed that, 94% of the cassava starch producers are women. 81% of the producers obtained their raw material from their farms. The main tools used in the extraction process are kitchen utensils, and the entire process is carried out manually. 60% of the producers find their method of processing to be a strenuous, with the most difficult unit operation being that of rasping. The end use of the starch produced is primarily for household use. The diagnosis carried out in the Nkong Abok locality enabled to obtain information on the extraction and the physico-chemical properties of the starch produced in this region of the country. The extraction process was characterized by an average yield of 17%. The quality of the cassava starch was on average, 90.98% of total starch content. The technological properties of the starch showed; pasting properties ranging from 65.9 - 66.68, and peak viscosities ranging between 3944 - 4744mPa.S. The financial evaluation of the extraction process at the Nkong Abok locality revealed a negative gross profit of 3614447Fcfa. However, the proposed process showed that, with an investment of 111829300 Fcfa over a period of 5years, a net profit of 78 992 503 Fcfa we will be attained in the second year. The pay-back period of the proposed activity will be between the 1st and 2nd year. Hence, even though cassava starch extraction in the central region of Cameroon is handicapped with a lot of constraints, there exist solutions to render the activity profitable and capable of responding to the existing market.

Key words: Cassava, cassava starch, process, profitability.

RESUME

L'amidon de manioc est au Cameroun, l'un des produits dérivés des racines de manioc. A la différence des autres produits dérivés du manioc, les informations concernant; les modes d'utilisation, le procédé d'extraction, les producteurs, les conditions de transformation, le marché et la qualité du produit, ne sont pas bien connues. Ajouté à son faible positionnement par rapport aux autres produits dérivés du manioc, l'approvisionnement en amidon de manioc par les producteurs locaux au Cameroun ne répondrait pas à la demande du marché. Les différents utilisateurs (agro-industries, l'industrie de papeterie et de cartonnerie) prétendent que la quantité et la qualité de l'amidon ne répondent pas à leurs exigences. Afin de vérifier l'hypothèse posée, ce travail a consisté de ressortir avec les informations du secteur d'amidon de manioc dans la région du centre du Cameroun. Par conséquent, une enquête couplée à un diagnostic d'une localité donnée, ont été effectué dans la région du centre. Des résultats obtenus de l'enquête, 94% des producteurs d'amidon de manioc sont des femmes, 81% des producteurs obtiennent leur matière première de leurs champs. Les outils principaux utilisés dans le procédé d'extraction de l'amidon sont des ustensiles de cuisine et le procédé est totalement manuel. 60% des producteurs trouvent leur méthode laborieuse, le râpage étant l'opération unitaire la plus pénible. L'amidon produit est principalement pour l'usage ménager. Le diagnostic effectué dans la localité de Nkong Abok a permis d'obtenir les informations sur le procédé d'extraction et aussi de déterminer les propriétés physico-chimiques de l'amidon produit dans cette région du pays. Le procédé d'extraction s'est caractérisé par un rendement moyen de 17%. La qualité de l'amidon de manioc obtenue est en moyenne de 90,98% en termes de teneur en amidon. Les propriétés technologiques de l'amidon ont montré que : la température d'empattage des amidons varie de 65,9 à 66,68°C, et leurs viscosités de pic varie entre 3944 à 4744 mPa.S. L'évaluation financière du processus d'extraction dans la localité de Nkong Abok a indiqué un résultat net négatif de 3.614.447 Fcfa. Cependant, le procédé proposé a démontré que, avec un investissement de 111.829.300 Fcfa sur cinq ans, le résultat net est de 78.992.503 Fcfa dès la deuxième année de l'investissement. Le retour sur investissement de l'activité est situé entre la 1ère et 2ème année. Par conséquent, quoique l'extraction d'amidon de manioc dans la région centrale du Cameroun soit handicapée avec plusieurs contraintes, ils existent des solutions pour rendre l'activité profitable et apte à répondre au marché existant.

Mots clés : Manioc, amidon de manioc, procédé, rentabilité

INTRODUCTION

The importance of starch in the agro-industrial world derives from its diverse and multi-purpose character. This confers starch with a wide range of function in the manufacture of many food and non-food products. Almost all major industries have found some applications for starch. In food industries, starch is used to impart "functional" properties to processed foods such as thickening, binding, filling, and taste. Users of starch in non-food industries include; the textile, paper, plywood, adhesive, biofuel, beverage and pharmaceutical industries (Fuglie et *al*., 2006).

In developing countries, the starch obtained from root and tuber crops is produced in small quantities and its primary use is in domestic consumptions. This is reflected by the production of starch by Africa in 2002 (0.02 million tons of starch content from Cassava) (Fuglie et *al*, 2006). Despite the importance of starch for the different industries, information about starch production, utilization and prices is sparse and incomplete, especially for developing countries. Much of these data are held privately by firms that may be reluctant to share them due to market advantages that such data may impart (Fuglie et *al*, 2006).

In Cameroon there exist abundant and varying sources of starchy food crops among which, the roots and tuber crops. The main role of starchy food crops is for domestic consumption, particular as a source of human calorie. In Cameroon, cassava ranks first amongst root and tuber crops in terms of total production, with a total production of 3,808,239 tons in 2010 (AGRI-STAT, 2012). Cassava is hence the main root and tuber starch source in the country. Cassava is mostly cultivated in the rural areas, on marginal soils, where the great part of the population is essentially poor (87% of poor people live in rural areas (final report, 2009). The women who are the main actor of this sector represent the greatest share of the poor population, with 52% of poor household members being women particularly affected, (final report, 2009). For these reasons among others, cassava has been for long considered a poor man's crop. In Cameroon, local cassava starch is mainly extracted via traditional methods, only one semi-industrial unit is known in Souza situated in the littoral region. The main end purpose of the local starch produced is for laundry services. The Cameroonian principal market for local cassava starch is dominated by dry cleaners, but there is an industrial market being that of the card-board industry and a potential market in the agro-food industry (Tolly, 2013). The dry cleaners represent the smaller share of the starch market in Cameroon, while the industries such as; Nestlé with 1200 tons of starch imported yearly, as well as the cardboard and textile industries with 1500 tons imported per year represent the larger share of the market (Duval et *al*., 2013). The amount of imported starch reveals the low use of local cassava starch by the industrial sector. According to these industrial users, Cameroonian starch does not respond to their requirements, reasons why they prefer to import their starch. It is believed that the reasons for the poor quality and inadequate supply of local cassava starch are principally due to; the extensive cassava production system, the low cassava root yields, poor selection of the cassava variety, lack of a standard cassava transformation process, lack of adequate transformation equipment. However, the producers are not the sole responsible; the cassava value chain itself is auto-regulated and poorly organized. Added to this fact, cassava had received less support from scientific research as other products such as yams, taro, potatoes, Irish potatoes (Njintang, 2003; Medoua, 2005; FAO, 2010). It is only in the past decade that cassava and the products derived from it have given more attention by scientific research. Therefore, in order to diversify and improve the transformation of cassava, several research projects have been introduced in the agricultural policy of Cameroon. Among the projects exists; PNDRT, PGPA, C2D 'Manioc', and IFAD, PIDMA, 'Projet Manioc' PRASAC. In collaboration with research institutions such as; IRAD and IITA, these projects have been put in place in Cameroon, with the objective of developing cassava production and transformation, and hence, exploiting the business opportunities. DONATA Cameroon is one of those projects that have embraced this concept. In Cameroon, DONATA has adopted the approach of innovation platforms, with two entry points. The first entry point being: access to the improved varieties of cassava and improvement of the soil fertility, while the second entry is concerned with improvement of transformation and commercialization of cassava. It is in the second entry point that this work finds its context. The cassava product concerned in this work is cassava starch. DONATA Cameroon aims at improving the quality of the cassava starch produced by its platforms, as well as increase the process yields. By so doing, this will help contribute to respond to the quality and quantity requirements required by the industrial users. In order to do that, DONATA Cameroon needs to acquire information concerning the actors of the production system, the conditions surrounding the production system, the process yield and quality of the cassava starch obtained from the production system. Hence, the present work had as main objective to evaluate the local transformation practices and coming out with proposals for the improvement of the production system, and specific objectives;

•Characterize the local cassava starch production system in the central region of Cameroon, focusing on one of DONATA's innovation platforms, bringing out; the different constraints faced by the actors in relation to their production system, evaluating the technological and financial aspects of the production system, and secondly proposing an improved economically profitable process for the actors of the production system.

PRESENTING DONATA

Dissemination of New Agricultural Technologies in Africa (DONATA) is an initiative of the African Union under its New Partnership for Africa's Development. It is coordinated by the Forum for Agricultural Research in Africa (FARA), an Africa-wide organization that oversees the activities of regional research associations, which in turn facilitate the work of national agricultural research systems. DONATA serves three regions: West and Central Africa, Eastern Africa, and Southern Africa. It is funded by the African Development Bank. In West and Central Africa, DONATA is coordinated by CORAF /WECARD. This regional organization, based in Dakar, Senegal, brings together the national agricultural research systems of 22 countries. The DONATA focus crops were selected in 2007 at a consultation workshop of researchers, agribusinesses, farmers, extension agencies and development organizations. All three regions initially chose rice as one of their crops, but the donor was already supporting major projects on rice in several countries, and wanted to learn from their work before investing further in this crop. After some discussion, all three regions chose to focus on maize plus one other crop: cassava in West and Central Africa, orange-fleshed sweet potatoes in East Africa, and sorghum in Southern Africa.

DONATA Cameroon

DONATA in Cameroon got off to something of a false start, caused by a combination of factors. It tried to focus on both maize and cassava. Support from various institutions was lacking, and the focal point was not able to formulate a suitable approach. Several farmers' groups were established, but their efforts were hampered by a lack of understanding of the innovation platform approach.

So when a new focal point took over in 2012, it was necessary to relaunch the initiative. He refocused it on a single crop, cassava, and sought the collaboration of organizations with the necessary expertise. DONATA Cameroon now uses two entry points: cassava production, coordinated by IRAD, and processing and marketing, coordinated by the University of Yaoundé II. Three of the original farmers' groups continued, and four new ones were added. These groups were called "comités de concertation villageois" (farmer consultation committees). They included farmers, the village chief, religious leaders, traders and processors. These groups were facilitated by the farmer leaders, supported by an extension worker. Each group had several subgroups in different villages to organize their activities. They obtained improved planting materials from the research institute, and organized training on production methods and marketing opportunities. After 8 months of working together, the consultation committees were ready for the next step. This was to add researchers from IRAD and the university, transporters, media representatives and two national non-government organizations (CNOP/CAM and RHORTICAM) to the mix. Adding this new set of actors converted the consultation committees into fully fledged innovation platforms.

Each platform covers both production, and processing and marketing. The new actors have boosted the capacity of the platforms, introduced new ideas and opened up new possibilities. That makes it more likely that the platforms will be sustainable

The Nkong-Abok innovation platform

"Together we cannot fail" is the slogan of the Nkong-Abok Nkolbibanda innovation platform, about 50 km from Yaoundé. This group boasts 270 actors (170 of them women), divided into four subgroups in the villages of Mfida 3, Nkong-Abok, Yegue and Koli. It started out as a farmers' group that began collaborating with IRAD in 2005. In early 2012 it created a farmers' consultation committee, and in November that year it became a fully-fledged innovation platform when researchers, extension staff and transporters joined. Each member contributes FCFA 1000 (about $2) a month. This money goes to pay expenses, including the wages of some young labourers to clear a 10 hectare plot, where the group wants to multiply disease-resistant cassava cuttings supplied by IRAD. This land has been donated by the Catholic mission and the local mayor. The aim is to grow enough cuttings to supply the people involved, and to support the farmers in producing disease-free cassava planting materials. If this is successful, says 'Maman Douala', the chair of the platform, it will bring in higher incomes and maybe even attract men to cassava production and marketing.

Cassava is the main tuber crop cultivated in the Nkong Abok innovation platform. In the Nmom Nam village, the innovation platform is made up of 42 members who are predominantly women. In this platform, cassava cultivation, processing and marketing is a woman's activity. They are involved at all levels of the cassava value chain, from the farm to the market. For these women, cassava is consider as the 'women's cocoa'. They use cassava (and the derived products) to feed their families, to send their children to school, and to overcome any general problem that may arise at the level of their household. Among the cassava derived products, batôn de manioc is the most produced and sold, followed by; dry chips, fufu, flour, gari and lastly cassava starch. At the level of the innovation platform, certain conditions need to be fulfilled in order to join the platform. One of these conditions is that, each member must possess a farm of at least 1 hectare in size intended for cassava production. Hence, all the women members of the platform are capable of producing 2-10 tons of cassava, and up to 30tons with improved varieties. For more than a decade cassava has been a key element of their food system. The nature of the market for their cassava product is mainly a short circuit, characterized by direct relationships with the buyers and sellers. However they do transport their products (cassava and derived products) to the main markets of Yaoundé, particular at the MVOG ATANGANA MBALLA market. The transportation facility here is a taxi size car. The women rent the services of a driver to transport the final product to the market when need be. For the cassava starch market, it is solely a direct short circuit type. The large buyers are dry cleaners who come to the village to acquire the product. The minor customers are those in the locality who desire to harden or render the texture of their clothes firm.

CHAPTER ONE: LITERATURE REVIEW

I.1 Cassava

Cassava is a staple food that provides carbohydrates or energy, for more than 2 billion people in the tropics (Ukwuru and Egobnu, 2013). It is a higher producer of carbohydrate per hectare than the main cereal crops and can be grown at a considerably lower cost (Ukwuru and Egobnu, 2013). In order of importance, cassava ranks fourth as the main source of industrial starch production after maize, wheat, and potato in the developing countries (Henry and Westby, 2000). It is the fourth most important crop for farmers in the tropics after rice, wheat and sugar, consumed by up to a billion people globally (FAOSTAT, 2010).

I.1.1 Cassava origin

Cassava domestication began 5000 – 7000 years BC in the Amazon, Brazil (Allen, 2002) and it was distributed by Europeans to the rest of the world (Henry & and Hershey, 2002). In, Africa Cassava was first introduced in the Congo from South America about 400 years ago. Currently, cassava is cultivated in around 40 African countries, stretching through a wide belt from Madagascar in the Southeast to Senegal and to Cape Verde in the Northwest (Nweke, 2004). The Portuguese carried it from Brazil to Africa in the late sixteenth century as a cheap staple to feed slaves. Cassava was rapidly taken up by African farmers near the coast, but only began to penetrate the interior in the eighteenth and nineteenth centuries. Due to the highly toxic characteristics of bitter cassava, the techniques of processing it travelled with the plant itself and are found all over Africa. From this point we find both a large number of local roots (Blench, 2014). Both sweet and bitter cassavas were brought to Africa, but the bitter cassavas are much more widespread, since the yield is higher and they can be stored for long periods, unlike sweet cassavas which must be eaten when they are taken from the ground (Blench, 2014).

I.1.2 Cassava taxonomy

Cassava, as known in English, is “manioc” in French, “yuca” in Spanish, and “mandioca” in Portuguese, the names for the cassava plant vary depending on the region: yucca (Central America), mandioca or manioca (Brazil), tapioca (India and Malaysia) and cassada or cassava (Africa and Southeast Asia) (BeMiller and Whistler, 2009). In North America and Europe, the name cassava is generally applied to the roots of the plant, whereas tapioca is the name given to starch and other processed products (Alves, 2002).

Cassava is classified scientific as follows;

Kingdom: Plantae

Class: Dicotyledoneae

Family: Euphorbiaceae

Tribe: Manihoteae

Genera: Manihot Tournefort

Species: *Manihot esculenta* Crantz (Alves, 2002).

I.1.3 Morphology of cassava

Cassava plant is a tall semi-woody perennial shrub or tree, which can grow up to 7 m high The length of the roots varies between 15-100 cm and the weight can reach up to 3 kg for a root (No author, 2008). The outer bark of the root is smooth, light brown to yellowish grey in colour while inner bark is cream-green in colour and wood is soft in consistency. The cassava leaves have a petiole light greenish to red in colour. The leaves are dark green above and pale light greenish greyish underneath, sometimes variegated and pedicels are light green to red (Bahekar et al, 2013).

Picture 1: Cassava plant

Picture 2 Cassava roots

I.1.4 Ecology of cassava plant

Cassava is distributed between latitudes 30°N and 30°S (Costa and Silva, 1992; Alves 2002). It is a lowland tropical plant and needs a warm moist climate with mean temperature of 24° -30°C (Onwueme, 1978; IITA, 1990; Nassar, 2005). Cassava can grow in the semi-arid tropics with an annual rainfall less than 800 mm, but the ideal rainfall is 1000 to 1500 mm per year (Alves, 2002). Cassava can be cultivated on arid and semiarid land where other crops, such as corn, do not thrive (Lin et al., 2011). It can tolerate drought and can grow in low nutrient soils but does not tolerate high concentrations of salts with a pH above 8, excess soil moisture, and temperatures of 10°C and below (Onwueme, 1978; Lozano et al., 1980; IITA, 2001; Benesi, 2002; Mkumbira, 2002; Nassar, 2005).

I.1.5 Composition of cassava roots

Cassava tuberous roots are composed of a peel which represents about 10-20% of the tuberous root. The cork layer represents 0.5-2.0% of the total tuberous root weight .The fresh root of cassava contains 30% to 40% dry matter of which 85% is starch. The fleshy edible portion makes up 80-90% of the tuberous root and is composed of 60-65% water, 30-35% carbohydrate, 1–2% protein, 0.2-0.4% fat, 1.0-2.0% fibre, and 1.0-1.5% mineral matter (Nassar and Costa, 1976; Onwueme, 1978; Nassar, 1986). The peel of cassava roots contains slightly more protein than is found in the flesh. Therefore, peeling results in loss of part of the valuable protein component of the root. On dry solid basis, starch is a major component of cassava roots, accounting up to 77-94% w/w, the rests are protein (1.7-3.8% w/w), lipid (0.2-1.4% w/w), fibre (1.5-3.7% w/w as crude fibre, i.e. cellulose and lignin) and ash (1.8-2.5% w/w) (Breuninger et al., 2009). Cassava is reasonably rich in calcium and vitamin C, but the thiamine, riboflavin, and niacin contents are not as high. Large proportions of these nutrients have been reported to be lost during processing (Bourton et al., 2010). There exist sweet and bitter cassava varieties; sweet cassavas are normally used in direct human consumption, while bitter cassavas (which have higher starch content) are used as animal feed or processed into industrial inputs (Vessia, 2007).

Table 1: Chemical composition of Cassava roots in percentage w/w

Composition	Cassava roots
Moisture	59-70 (Wet basis)
Starch	77-94 (Dry basis)
Protein	1.7-3.8 (Dry basis)
Lipid	0.2-1.4 (Dry basis)
Fibre	1.5-3.7 (Dry basis)
Ash	1.8-2.5 (Dry basis)

Source: (Monceaux, 2009)

I.1.6 Cyanide content and toxicity of cassava roots

Cassava contains cyanogenic glucosides in the form of linamarin (93%), and to a much less extent, lotaustralin (7%) (Aworh, 2008). The cyanide levels range from 10 to 450 mg/kg of fresh root. The poison tends to be more concentrated in the skin of the root (Bourton et *al*., 2010). In so-called sweet cassava the parenchyma contains only a small amount of cyanogens, so that after peeling, these roots can be safely boiled and eaten, as occurs in the South Pacific (Bradbury and Holloway, 1988). The bitter taste of bitter cassava is very largely due to linamarin (King and Bradbury, 1995). Generally bitter varieties have higher cyanide contents ranging between 100 and 400 mg equivalent HCN, while the sweet varieties have less than 100 mg (Hongbete, 2004).The amount of cyanogenic glucosides varies with the plant's age, variety, and growth environmental conditions such as; soil, moisture, temperature (Nartey *et al*., 1977; Bokanga, 1994). Coursey (No date) has suggested the following as a rough guide to cyanide toxicity;

- Innocuous: less than 50 mg HCN/kg of fresh, peeled root
- Moderately poisonous: 50 - 100 mg HCN/kg of fresh, peeled root
- Dangerously poisonous: over 100 mg HCN/kg fresh, peeled root

I.1.7 Production and utilization of cassava roots

I.1.7.1 Cassava world production and utilization

The estimated total world cassava production in 2010 was 230 million tonnes, which is an increase of 25% since 2000 (FAO, 2012). The data in Table 3, suggests that, even though cassava originated in Latin America, Africa is the largest cassava producer in terms of surface area cultivated and production, and cultivates over 50% of the global crop. Asia ranks second to Africa, while Latin America and the Caribbean rank third. Despite the large surface area cultivated and the high volume of production, its yield potential in Africa is lower than the global average. In terms of yield, Africa ranks third to Asia and Latin America and the Caribbean, which may be due to the fact that cassava is grown mostly in poly-culture in Africa. The average world cassava yield in 2010 was estimated at 12.4 tonnes per ha. African countries present the lowest yields and Asian countries present the highest yields. Maximum yield was reported to be 34 tonnes per hectare in India (FAO, 2012). The regional statistics provided tend to obscure production realities at country level. Prakash (no date) reports that around 60% of global cassava production is concentrated in five countries: Nigeria, Brazil, Thailand, Indonesia, and the Democratic Republic of Congo (formerly Zaire).

While cassava is grown in the tropics, it is used worldwide in diverse forms. It is the primary staple for some tropical and sub-tropical nations (especially in Africa and Asia), and it is used as a main carbohydrate source in animal feed and as a raw material in the manufacture of processed food, animal feed, and industrial products (Balagopalan, 2002). Both fresh storage roots and leaves/young plant tips have multiple end uses that include:

i) direct human consumption,
ii) on-farm feeding of animals and commercial production of animal feed;
iii) production of starch and starch derivatives;
iv) production of ethanol for use as a biofuel (automotive fuel) or in alcohol production;
v) compost;
vi) Mushroom production.

In relation to direct human consumption, the forms in which cassava is eaten in Africa include: boiled fresh roots, cassava flours (fermented, unfermented), granulated roasted cassava paste called gari (aka tapioca), granulated cooked cassava (attleke, kwosal), fermented pastes (waterfufu, chikangwa, couscous), sedimented starches, drinks, leaves (cooked as vegetables) and medicine (Hillocks, 2002). Farhina is also eaten mostly in Latin America and the Caribbean.

Until 2004, cassava was mainly grown in Africa for food and to a lesser extent for animal feed, but the percentage destined for other uses increased steadily over time. In 2004, only about 60% of Africa's cassava production was consumed as food (Ntumngia, 2010). It has been described as a subsistence crop for rural householders, but it is increasingly becoming a cash crop in Africa (Nweke et al., 2002), where the majority of cassava produced (88%) is used for human food (Westby, 2002). According to Nweke et al. (2002), cassava plays five important roles in African development: famine-reserve crop, rural staple food, cash crop for both rural and urban households and, to a minor extent, raw material for feed and chemical industries.

Table 2: World regional Trends in Surface Area Cultivated, Production, and Yield of Cassava (1980 to 2005)

Production	Region/World	Statistics				
Surface		**1980**	**1990**	**2000**	**2004**	**2005**
Area	World	13556	15605	16884	18475	18696
(000 ha)	Africa	7035	8982	10907	12252	12354
	Latin America and th Caribbean	2471	2438	2281	2696	2649
	Asia	3803	3941	3468	3511	3429
Production	World	123796	155127	178009	203618	203341
(000 mt)	Africa	48492	71769	96988	108470	109755
	Latin America and the Caribbean	27668	28792	28258	34727	34094
	Asia	44419	51689	49937	60245	56082
Yield	World	91	99	105	11.02	109
(hg ha^{-1})	Africa	70	80	89	8.85	89
	Latin America and the Caribbean	102	107	113	12.88	117
	Asia	117	131	144	17.16	164

Source: Howeler, 2006; FAOSTAT, 2006 and Prakash, 2007

I.1.7.2 Cassava production and utilization in Cameroon

Root and tuber production, especially cassava, generally relies on smallholders whose farms are mostly less than 2 ha (cassava plots' acreage). It can also be found in mid-size farms (2-4 ha) and larger producers (over 4 ha). A survey conducted in 1995 exhibited the following distribution of cassava farms which, although out of date, has been confirmed by FAO in 2010.

It is important to recall that local cassava varieties in humid areas require a 12-18 months production cycle, expanding to 15-24 months in highlands and sub-Saharan conditions. The growing cycle has however been reduced to 10-15 months for the PNDRT popularized varieties in humid conditions, and 15-18 months in other areas (Tolly, 2013). With the introduction of improved varieties, the productivity at farm level has increased from about 8-10 T ha^{-1} to over 20-30 T ha^{-1} and the annual production in Cameroon is now estimated at over 3 million tons. The productivity at farm level depends largely on the cultural practices use, the variety cultivated, the site-specific conditions and farm maintenance. Most smallholder farmers grow a mixture of local and improved varieties, associate other food crops such as maize and groundnut and hardly apply manure/fertilizer (Tolly, 2013).

In Cameroon, cassava ranks first amongst root and tuber crops in terms of total production, with the; Centre, East and South and South West regions being the most productive areas (AGRI-STAT, 2012). In 2009, Cameroon was the 19th cassava producing country (FAOSTAT, 2010).

Cassava plays an important role as a source of food, employment and income for many people in Cameroon (Ngeve, 2001). It is the main starchy staple with 80% of rural and urban households consuming cassava and cassava derived products on a daily basis (Essono *and al*., 2008). The way it is consumed (processed, prepared, and packed) is heterogeneous across cities, ethnic groups, or regions. Some consumers prefer it as a fresh root; others prefer processed products (fufu, gari, or sticks). Fresh roots represent 50% of total quantities consumed in cities and villages for all end products of the value chain, which is a much higher share than in the 90s. Cassava products represent 60% of the roots and tubers' market share (in value), comprising 40% of processed products (fufu, gari, sticks, and waterfufu) and 20% of fresh roots (Tollo, 2013). Cassava and its products for example; baton, paste, flour, fufu, gari, chikwangue and starch are being sold both in Cameroon and elsewhere in central Africa for the rapidly growing urban populations (Njukwe *et al*., 2012b). Cassava by-products are the first source of starchy food in the whole of Southern Cameroon (PNDRT 2003, ECAM III 2007). Cassava produced in Cameroon is used for food, animal feed and other transformed products particularly gari, waterfufu, cossettes, bâtons de manioc, mintoumba, miondo and starch. These products are tied to specific regions of the country. Thus, gari and waterfufu are widely processed in the South West and North West Regions of Cameroon, while bâtons de manioc and mintoumba are dominant cassava products in the Centre Region. Since most of the processing units are traditional or small-scale, there is need to industrialize the value chain to make it more profitable to all the actors. (Ngome, 2013). The main steps for cassava processing in Cameroon and the resulting products are shown in the figure below

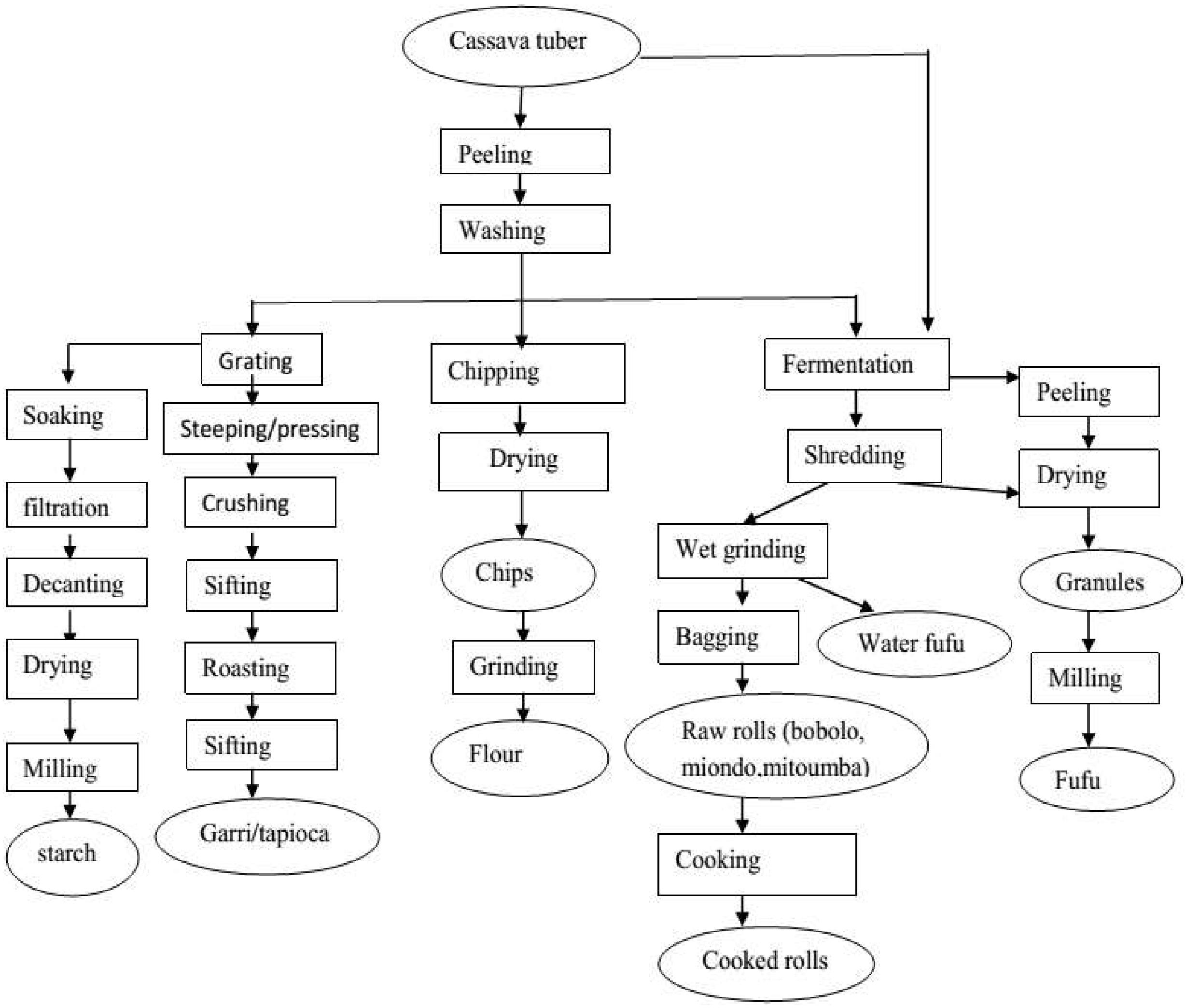


Figure 1: Main operations in processing cassava in Cameroon (Mbairanodji, 2007)

I.1.7.3 Cassava processing

Today, there exists a great diversity of processing methods found in the various parts of the world where cassava is consumed (Lancaster *et al*., 1982). Traditional cassava processing methods involve several steps among which; peeling, soaking, grinding, steeping in water and left in air to allow fermentation to occur, drying, milling, roasting, steaming, pounding and mixing in cold or hot water. Specific combination of these steps leads to a myriad of different cassava products with acceptable taste to wide range of consumers (Bokanga and Otoo, 1991). Cassava processing by traditional method is labour-intensive but the application of the improvement of the processing technology has reduced processing time, labour and encourage further production (Adeniji *et al*., 2001). Cassava processing improves palatability, increases shelf-life, facilitates transport and, most importantly, detoxifies cassava roots by removing cyanogen (Nweke, 1994; Westby, 2002). Cassava is consumed in many forms particularly, fresh for sweet varieties, boiled or processed but also for its leaves which serve as vegetables and is largely grown by smallholder farmers, with the main production system being intercropping (Agwu and Anyaeche, 2007). Cassava processing is a very important operation in Africa. It is estimated that 70% of cassava is processed before use (Agueguia and *al*, 2000).

I.1.7.3.1 Reasons for cassava processing

Fresh cassava roots cannot be stored for long because they rot within 3-4 days of harvest. They are bulky with about 70% moisture content, and therefore transportation of the tubers to urban markets is difficult and expensive. The roots and leaves contain varying amounts of cyanide which is toxic to humans and animals, while the raw cassava roots and uncooked leaves are not palatable. Therefore, cassava must be processed into various forms in order to increase the shelf life of the products, facilitate transportation and marketing, reduce cyanide content and improve palatability. The nutritional status of cassava can also be improved through fortification with other protein-rich crops. Processing reduces food losses and stabilizes seasonal fluctuations in the supply of the crop (Hahn, 1986).

1.1.7.3.2 Constraints in the traditional processing of cassava

Among the various constraints linked to traditional cassava processing, environmental, agronomic and socio-economic factors are explained below:

Environmental factors

During the rainy season, sunshine and ambient temperatures are relatively low for processing cassava, particularly in lowland humid areas where cassava is mainly grown and utilized. In other localities, particularly in savannah zones, water which is essential for processing cassava, is not easily available. During the early rainy season, the dry matter content of roots is usually lower than in the dry season, which can result in a lower yield of products. In the dry season when the soil is hard, harvesting and peeling tubers for processing are difficult and result in more losses (Hahn *et al*., 1985).

Agronomic factors

Planting and harvesting time, and the age of plant (from planting to harvesting), all affect starch content, yield and quality of products. Other agronomic practices such as intercropping, fertilizer application and spacing can also affect yield and crop quality (Hahn *et al*., 1985).

Socio-economic factors

Harvesting and transporting of roots from farm to homestead and subsequent processing are mainly done by women. Most of the steps in processing are carried out manually using simple and inexpensive tools and equipment that are available to small farmers. Cassava processing is labour intensive and productivity is usually very low. Transport of products to markets is made difficult by the poor condition of rural roads. The drudgery associated with traditional processing is enormous and the products from traditional processing methods are often contaminated with undesirable extraneous matter. Some of the products are therefore not hygienic and so are of poor market value (Hahn et *al*., 1985).

I.2 Starch

Starch, which is the major dietary source of carbohydrates, is the most abundant storage polysaccharide in plants, and occurs as granules in the chloroplast of green leaves and the amyloplast of seeds, pulses, and tubers (Sajilata, et *al*., 2006). Chemically, starches are polysaccharides, composed of a number of monosaccharides or sugar (glucose) molecules linked together with α -D-(1-4) and/or α -D-(1-6) linkages. It finds multiple applications in various industries such as pharmaceuticals, textiles, paper, and the food industry. Starch is the major source of calories and dietary energy in most human food systems. There exist two forms of starch; native starch and modified starch. Native starches are produced through separation of naturally occurring starch from either grain or root crops such as cassava, maize and sweet potato, and can be used directly in producing certain foods such as noodles (Wang et *al*., 1996). Native starch is the basic starch product that is marketed in the dry powder form under different grades for food, and as pharmaceutical, human and industrial materials. Native starches have limited usage, mainly in the food industry, because they lack certain desired functional properties. For those characteristics which are maintainable with native starch, modified starch can be used for other industrial applications through a series of techniques, chemical, physical and enzymatic modification (Feuer, 1998). Thus, modified starch is native starch that has been changed in its physical and/or chemical properties.

I.2.1 An overview of world starch production

The total utilization of starch in the world in 2009 was estimated to be 68 million tons (USDA, EU Commission). The most common sources of food starch are corn, potato, wheat, cassava/tapioca and rice. Historically, corn has been the major raw material from which starch is extracted. This source constituted approximately 81.2% of the total global starch market in 2000 and rose slightly to 82.6% by 2007. While potatoes and wheat cumulatively supplied over 15.1% in 2007 (up from 13.9% in 2000), other raw materials, primarily cassava comprises the category "Others". Between 2007 and 2009, cassava starch had increased its market value and holds approximately 7.5% of the world starch market (Starch Conference, 2011).

Table 3: World-wide starch production and the major sources of material

Product	Quantity (10^{6t}) in 2003		
	USA	Europe	Rest of the world
Maize starch	29.2	4	10.9
Wheat starch	0.5	3	1.1
Potato starch	0.1	1.9	0.8
Other starches	–	0.1	2.5
Total	29.8	9	15.3

Source: Bragança and Fowler, 2004.

I.2.2 Composition of starch

Starch is a polymer of α-D-glucose. It occurs in higher plants species, in the form of roughly spherical granules, ranging from 2 to 100µm diameter. The granules consist of about 77% starch and about 1% other dry matter (lipids, proteins, and minerals), the remainder of the mass being water (Walstra, 2003). Starch is composed of two basic molecular components: amylose and amylopectin. These are identical in their constituent basic units (glucose), but differ in their structural organization (Niba, 2006).

I.2.2.1 Amylose

Amylose is composed of D-glucose molecules, which are linked in an α-1→4 conformation. The glucose monomers therefore form a linear straight chain polymer. Amylose is slightly branched, and has a molecular mass of 105 to 106 g/mol (Brian et *al*, 2009.). The chains can easily form single or double helices. Amylose is less predominant (about 20%) and typically constitutes about 20–40% in proportion (Praznik et *al*. 1994.). Amylose contains α-1→4 glycosidic bonds and is slightly soluble in water. It usually contains 200–3000 units. Amylose is the key component involved in water absorption, swelling, and gelation of starch in food processing.

High amylose starches are therefore most commonly applied in food products that require quick-setting gels such as candies and confectionery formation (Niba, 2006).

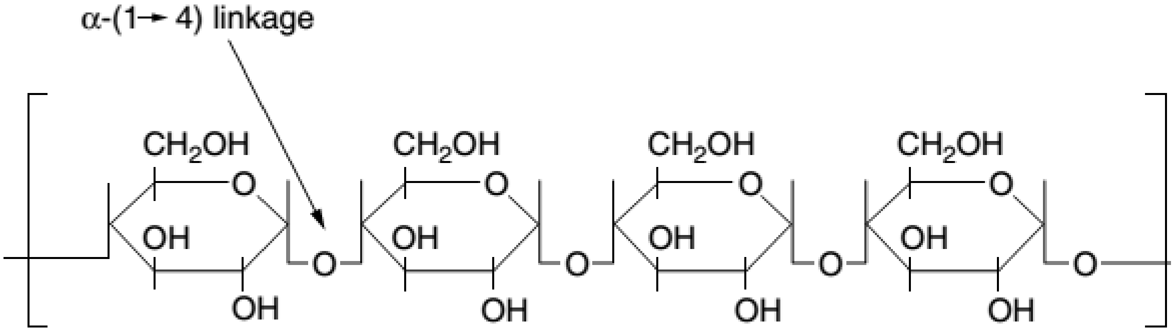


Figure 2 : Chemical structure of amylose, with glucopyranose unit linkage

I.2.2.2 Amylopectin

Amylopectin consists of D-glucose units which are linked in an α-1→ 4 conformation as is the case with amylose, as well as D-glucose units in an α-1→ 6 conformation. Amylopectin is therefore highly branched as the α-1→ 4 linear chains are punctuated with the α-1→ 6 linkages. The α-1→ 6 constitutes about 5% of the structure of amylopectin and gives rise to the branching (Oates, 1997). Amylopectin has a molecular mass of 107 to 109 g/mol. Branch points occurs approximately every 20–30 α-linkages (Brian *et al.*, 2009). The ratios of amylose to amylopectin vary among starch sources and play a considerable role in determining reactions and physicochemical properties of starches in processing and food applications (BeMiller, Whistler. 1996; Hizukuri, 1996).

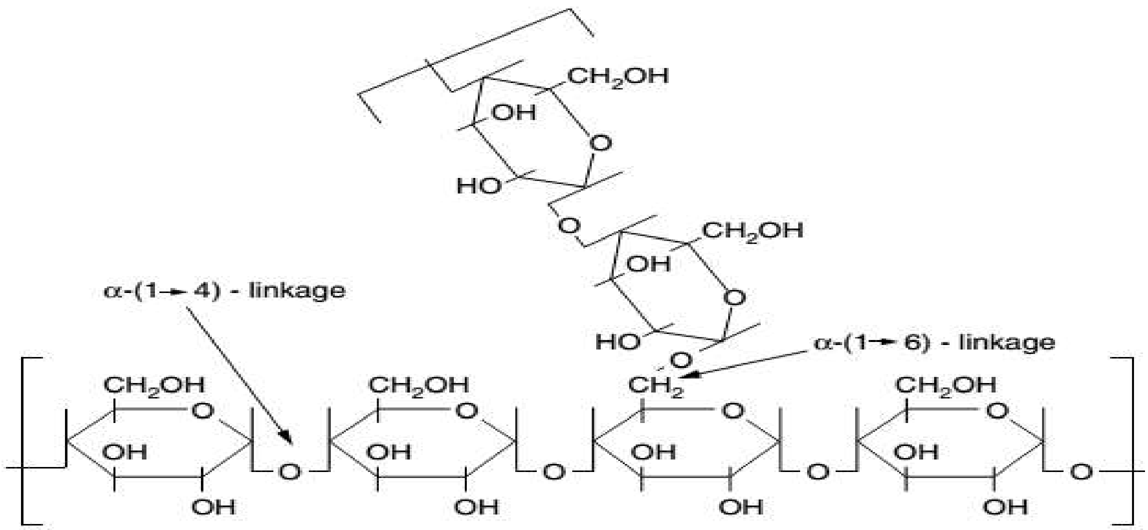


Figure 3 : Chemical structure of amylopectin with glucopyranose unit linkage

I.2.3 Starch physico-chemical properties and functionality

The application of starch in food products is greatly influenced by its physicochemical properties and interactions with various components. The reaction of starch molecules in foods is essential for the multiple properties that they contribute to the quality of food products. Gelatinization, retrogradation, and pasting, which underlie starch functionality, are the three most important phenomena in starch applications. Functionality and physicochemical properties vary among starches as they are influenced by the ratios of amylose to amylopectin. High amylopectin starches for instance are preferred for high viscosity products (Niba, 2006.).

I.2.3.1 Starch gelatinization

Starch gelatinization is the collapse (disruption) of molecular orderliness (breaking of hydrogen bonds) within the starch granule along with concomitant and irreversible changes in properties such as granular swelling, crystallite melting, loss of birefringence, viscosity development, and solubilization (Niba, 2006). Gelatinization results in starch swelling, and formation of a viscous paste that may be opaque or translucent depending on the nature of the starch (HS Su et *al*, 1997). The temperature at which starch granules lose the Maltese cross in the presence of excess water is the gelatinization temperature, and this occurs between 58°C and 75°C.

During the first stages of gelatinization, water enters the amorphous growth rings, and it is there where all the initial swelling forces are concentrated. The periodicity of the semi crystalline stack remains unchanged as long as the crystallites can still be identified. Then, as the temperature is raised further, the crystallites become destabilized and the crystallization index decreases progressively to zero. Concurrently with this loss of crystalline order, the molecular (i.e. double-helical) order within the granule is also lost (Jenkins, 1998. Cooke, D. *et al*.1992). The swelling of the starch granule and the leaching of polysaccharides are often regarded as the final stages in the gelatinization process, as they require the prior loss of at least some of the ordered structures within the starch granule. If present in the granules, amylose will be preferentially leached over amylopectin during the process. (Tester, et *al*., 1990)

I.2.3.2 Starch retrogradation

Starch retrogradation has been used to describe changes in physical behaviour following gelatinization. It is the process that occurs when starch molecules re-associate and form an ordered structure such as double helices during storage (Atwell, et *al*., 1988.) Retrogradation is important in industrial use of starch, as it can be a desired end point in certain applications but it also causes instability in starch pastes. Structural modification, either by genetic means to change the pathway of starch biosynthesis or by means of chemical or physical modification of starch, has been employed to alter the process of retrogradation (Taylor & Francis, 2005).

In general, retrogradation takes place in two stages. The first and fastest stage is the formation of crystalline regions from retrograded amylose. The second stage involves the formation of an ordered structure within amylopectin. During the retrogradation, the molecular interactions (mainly hydrogen bonding between starch chains) occur. These interactions are found to be time and temperature dependent. In consequence of retrogradation the intermolecular distances between starch molecules diminish. This leads to the removal of water from gel, and in consequence dehydration of the material. The phenomenon could be observed as occurrence of water on gel surface, known as synaeresis (Karim *et al*. 2000, Napierała 1998).

I.2.3.3. Rheological or pasting properties of starch

Rheological properties of starch have been widely investigated using a Brabender Visco Amylograph and Rapid Visco Analyser (RVA). The RVA provides information on starch characteristics similar to the Brabender Visco Amylograph with additional versatility of testing parameters. (Liu, 2005).The RVA has the advantages of using a small sample size, short testing time, and the ability to modify testing conditions. A typical Rapid Visco Analyser profile from normal maize starch is shown in Figure 6. Other commercial starches give different values with a similar profile as normal maize starch. In this RVA profile, native starch granules are generally insoluble in water below 50˚C. Thus, the viscosity is low. When starch granules are heated, the granules absorb a large amount of water and swell to many times their original size. The viscosity increases on shearing when these swollen granules have to squeeze past each other. The temperature at the onset of this rise in viscosity is known as the pasting temperature as shown in Figure 6.

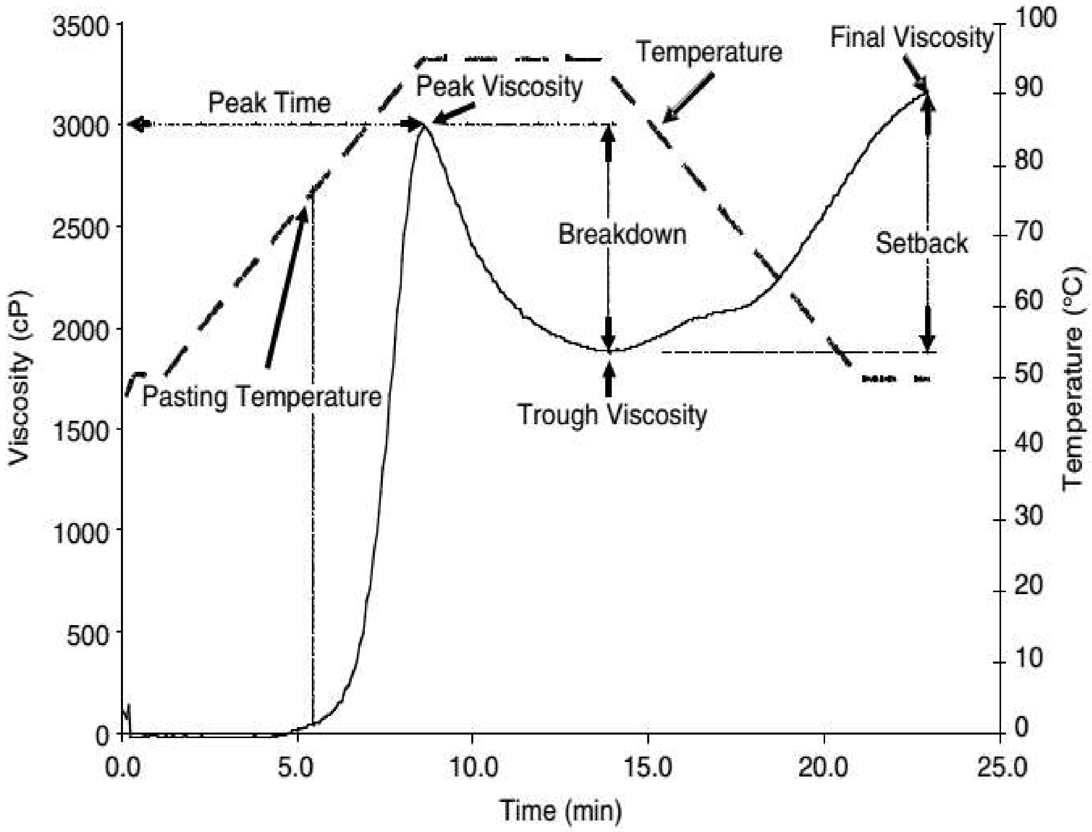


Figure 4 Typical RVA pasting profile of normal maize starch for viscosity (—) and temperature (---) as a function of time (Liu, 2005.)

The pasting temperature provides an indication of the minimum temperature required to cook a given sample. When a sufficient number of granules become swollen, a rapid increase in viscosity occurs. Granules swell over a range of temperature, indicating their heterogeneity of behaviour. The peak viscosity occurs at the equilibrium point between swelling and polymer leaching. Peak viscosity and temperature indicate the water binding capacity of the starch. As the temperature increases further and holds at a high temperature for a period of time, granules rupture and subsequent polymer alignment occurs, which decreases the apparent viscosity of the paste. This process is defined as breakdown. The viscosity at this stage gives an indication of paste stability. It is important to stress that only intact swollen granules can give paste viscosity, and not fragmented granules or solubilized starch substance. As the system is subsequently cooled, re-association between starch molecules, especially amylose, occurs to various degrees. In sufficient concentration this usually causes the formation of a gel, and the viscosity will be increased to a final viscosity. This phase of the pasting curve is commonly referred to as the setback region, and involves retrogradation of the starch molecules. The final viscosity gives an indication of the stability of the cooled, cooked paste under low shear (Liu, 2005).

I.3 Cassava starch

Starch is the main constituent of cassava; about 25% starch may be obtained from mature, good quality tuber. About 60% starch may be obtained from dry cassava chips and about 10% dry pulp may be obtain per 100 kg of cassava roots. Cassava starch is an important domestic and industrial raw material used in the manufacture of various products including food, adhesives, thickening agents, paper, and pharmaceuticals (IITA, 1990). The development of both the food and non-food use of cassava starch has made much progress and continues to have a bright future (Abraham *et al*., 1984; Srirotha *et al*., 1999). Cassava starch has many remarkable characteristics, including high paste viscosity, high paste clarity, and high freeze – thaw stability, which are advantageous to many industries (Gomes *et al*., 2005; Nzigamasabo and Ming, 2006; Zaidul *et al*., 2007).

I.3.1 Cassava starch extraction process

The production of native starch is a relatively simple process, that can be done at many scales, either at the household level, such as in some villages in north Vietnam, Cambodia and on Java island of Indonesia, up to very large and fully-mechanized starch factories, such as; those in Thailand, south Vietnam and in Lampung province of Indonesia. Starch factories usually prefer to process fresh roots, but whenever the harvesting season is concentrated into only a few months of the year, the starch factory can also process dry chips or wet starch. In general, the process is less efficient and the quality of the resulting starch is lower than when fresh roots are processed into starch. Four to five tons of roots are normally required to produce one tonne of cassava starch, but the ratio may be as high as ten to one, depending on the quality of the root. Most of the cassava starch industries are located in Asia. In this region, processing of cassava into starch is carried out by large scale factories in Thailand, Vietnam and China (Adam Prakash; no date). From a technological perspective, examining processes at both large and small scales indicates that there is diversity in cassava starch manufacturing (Balagopalan, et *al*. 2000). The processing yield (kg of recovered dry starch divided by 100 kg of fresh roots), consumption of water and possible electrical requirements have been reported in previous diagnoses (Marder, et *al*. 1996). The processing yield ranges from; 17% in Ivory Coast and in Colombia (Guesdon, 2002), 21% in Brazil (Vilpoux:, 1997) and up to 25% in Thailand (Sriroth, et *al*., 2000,). Water consumption per kilogram of starch was reported to be in the range; 21-40 L in Brazil (Marder et *al*., 1993.), 30 L in India (Trim, et *al*., 1996.), or up to 50 L in Colombia (Trim, et *al*.1996) Electrical energy requirements per ton of starch ranged from 14 kWh and 21 kWh in small- and medium-scale units in India (Sheriff, et *al*. 2005.). Despite these figures revealing potential differences between processes, they remain difficult to compare because of the use of different methodologies to estimate their components.

The various unit operations involved in the starch extraction process include washing, peeling, rewashing, rasping, sieving or screening, settling and purification, pulverization and drying. These operations require about 4.5–10 m3 of water per ton of roots (Nandy et *al*., 1996; Thangavel et *al*., 1998; Sriroth et *al*., 2000) which results in a dilute suspension of starch in water. According to NEPAD (2006), in the processing of cassava starch it is vital to complete the whole process within the shortest time possible, since as soon as the roots have been dug up, as well as during each of the subsequent stages of manufacture, enzymatic processes are apt to develop with a deteriorating effect on the quality of the end product. This calls for a well-organized supply of roots within relatively short distances of the processing plant and, furthermore, for an organization of the stages of processing that will minimize delays in manufacture. The process flow chart is in figure 7.

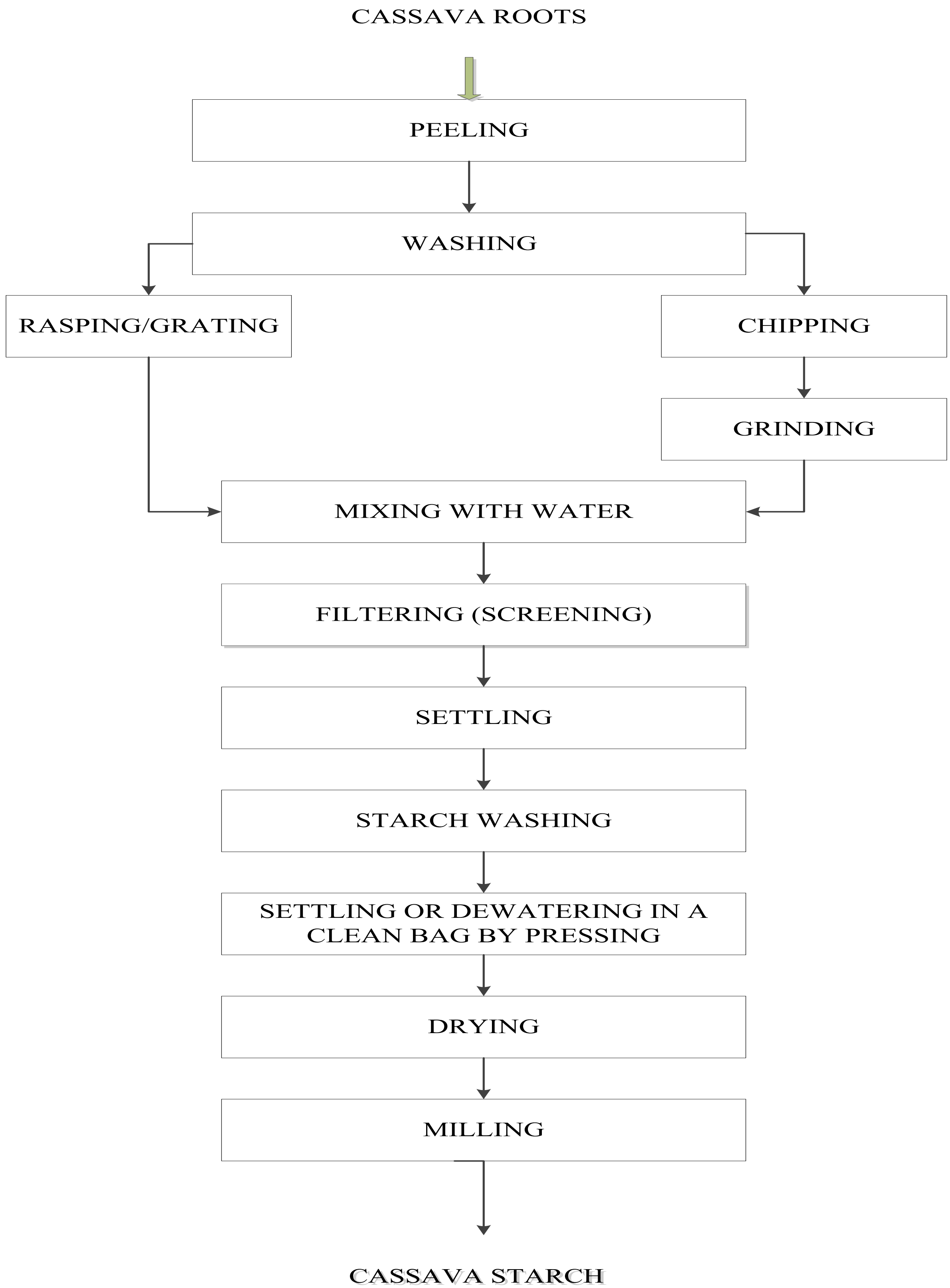


Figure 5 : Cassava starch extraction process

I.3.2 Description and Composition of cassava starch granules

Cassava starch granules are round, flat on one side and contain a conical pit which extends to a well-defined eccentric helium, ranging in size from 5–40 µm (Moorthy, 1994; Munyikwa *et al*., 1997). Cassava starch comprises 14 – 24% amylose (Ketiku and Oyenuga, 1972; Kawabata *et al*., 1984). Cassava starch comprises mainly the A-type pattern that is characteristic of cereal starches (Guilbot and Mercier, 1985). This A-type pattern is characterized by closely packed double helices compared to the more open B-type arrangement. Cassava starch also consists of 0.08% - 1.54% crude fat, 0.03% - 0.6% crude protein, and 0.75% - 4% phosphorus (Soni *et al*., 1985; Munyikwa *et al.*, 1997).

I.3.3 Factors influencing cassava starch composition and functionality

Unfortunately, starch functionality displays unpredictable variation, depending on the environmental conditions at the time of harvest (Asaoka and *al*., 1991; Defloor *and al*., 1998b; Moorthy and Ramanujam, 1986; Sriroth *and al*., 1998a; Sriroth *and al*., 1998b). In a recent study Sriroth et *al*., (1999) showed that the amount of rain during crop growth affects the starch pasting temperature, which increases during the dry season and decreases during the wet season.
According to a study carried out by Ebah-Djedji *et al*., 2012, harvest period has a significant effect on dry matter contents and starch yields. It affects more the dry matter contents than the starch yields during the vegetative cycle. So, Ebah-Djedji *et al*., 2012, concluded that, the tuberous roots of improved cassava varieties should be harvested at 13 months after planting to obtain optimum starch yields and dry matter contents. The delay in harvesting results in an increase in the starch content and a decrease in water content, but this advantage is offset to some extent by the increased fibre content, which makes the starch more difficult to extract (Sacithraa et *al*., 2013). The starch granules from older cassava roots are also characterized by decrease amylose content and an altered granule size distribution, gradually changing from a normal to bimodal distribution with increased harvest time. The environmental conditions also alter the response of the granules to water uptake (swelling power) (Sacithraa et *al*., 2013)
Cassava starch content reaches a maximum at the end of the rainy season. Less mature roots will be lower in starch content and higher in water, while overly (excessively) mature roots will be lower in recoverable starch content and have a woody texture, making starch processing difficult (Bemiller and Whistler, 2009). Mariscal and *al*., 2000, discuss that, in the Philippines, farmers who use cassava as a staple food may select low cyanide content varieties, whereas starch millers

prefer higher cyanide content varieties because they tend to produce higher yields, have higher starch content, and discourage crop theft (Mariscal and *al*., 2000).

Table 4: Physico-chemical composition of cassava starch (% dry matter)

Composition	Content
Water(g)	13.87 b)
Starch (g)	99.03 a) 95.88 b)
Amylose (% starch)	16.71 a)
Ash (g)	0.22 a)
Fibre (g)	0.37 b) 0.31 a)
Protein (g)	0.27 b)
Lipids (g)	0.20 a)
Acidity (ml NaOH)	2.63 b)
pH	6.9 a)
Granule size(µm)	12.3-15a)
Water holding capacity (g of water/ g of starch) c) 80°C	26.22
Swelling power (g/g) c) 80°C	34.8-46.8
Solubility (%) c) 80°C	18.4-20.8

Source : a) Numfor and Walter (1996) ; b) Vilpoux and Perdrix (1995) ; c) Pérez-Sira and Gonzalez-Parada (1997).

I.3.4 Food and non-food specifications for cassava starch

- **Food grade cassava starch**

Food grade cassava starch, according to the African Organization for Standardization (ARS), is defined as a white granular glucose polymer obtained by wet extraction process from mature cassava (Manihot esculenta Crantz) storage root or cassava chips or cassava flour. This African Standard specifies the requirements and the methods of sampling and test for food grade cassava starch. The requirements précised here will be in term of the compositional quality requirements.

Table 5: Compositional quality requirements of edible cassava starch

Analytical characteristic	Requirement	Method of test
Total acidity, %, by mass,	1.0 max.	AOAC
pH	5-7	ISO 1842
Cyanide content, mg/kg, max.	10.0	WD-ARS 844
Starch content, %, by mass, min.	95.0	ISO 10520
Moisture, % by mass, max	12.0	ISO 1666
Fibre, % by mass on dry weight basis, max.	0.2	ISO 5498
Sulphated ash, % by mass, max.	0.6	ISO 5809
Viscosity or pasting properties	33 – 34	Cstm
Acid insoluble ash, % m/m max	0.2	ISO 5985
Chloride, %, by mass, max.	0.64	ISO 5810

Source: AFRICAN STANDARD CD-ARS 846, 2012.

According to this African standard, every other starch which does not conform to the requirements in table 5 is classified as industrial or non-food starch.

I.3.5 Uses of cassava starch in the industries

Cassava starches are potential substitutes for wheat and maize – based starches (Rickard *and al*., 1991; Tian *and al*., 1991). Cassava is an important commodity in industry mainly because of its starch which is used in the production of various items.

As an ingredient in foods, native and modified cassava starch has been widely utilized as a stabilizer, with special emphasis on its lack of flavour contribution to food systems, allowing full and immediate detection of the flavour of the food itself (Anon, 1972; Anon 1991). Cassava starch is also used in making fructose syrup and fructose crystals which are used in the substitution of sucrose, glucose and synthetic sweeteners (Abraham, 1996). Cassava starch is also used in the manufacture of maltodextrin which substitutes for glucose as a sweetener; it is also used as a thickening agent (Balagopalan, 2002). Cassava starch, because of its low swelling and gelatinization temperature, is easily saccharified to simple sugars. These simple sugars are used in the production of sugar alcohols such as sorbitol, mannitol and maltol. Cassava starch has long been the starch of choice in baby food for its physical properties of texture and stability, as well as its low flavour contribution (Balagopalan, 2002). Cassava starch is preferred for food packaging over other types of starch because of its bland taste (Balagopalan, 2002)

In the paper and board industries, starch is used in large quantities at three points during the manufacturing process. The role of starch is to bind fibres, retain additives and increase strength (Breuninger *and al*). Cassava starch oxidized with hypochlorite or chlorine is useful in the paper industry because of its low viscosity, film strength and clarity in making glossy papers (Trim et *al*., 1996).

I.3.6 CASSAVA STARCH IN CAMEROON

Cassava starch in Cameroon is produced at a small-scale for commercial purpose and sold to clothe dry cleaners for hardening (NJUKWE et *al*., 2013). Together with beigner (or makra), cassava starch is considered as a minor product compared to the other cassava products (Ntumngia, 2010). However there exists some local industry supply of cassava starch such as Ferme Agricole du Sud which located in Batouri, Eastern Region which in 2010 supplied cassava starch for PLASTICAM Douala. The firm assesses cassava starch with regard to its stickiness compared with maize starch which is commonly used by many other cardboard makers located in Douala and Limbé (Tolly, 2013).

NJUKWE et *al*., (2013) describe cassava starch processing in Cameroon to be carried out as follows; Peel and wash fresh cassava roots. Grate, or chip and grind smoothly. Mix with a lot of clean water. Filter through a fine mesh sieve or through muslin cloth. Allow the filtrate to settle. Decant the supernatant. Wash off the starch residue several times with water to get white, odourless, and tasteless starch. Put in a clean bag and press to dewater. Spread thinly on a tray and sundry. Mill the dried cake finely and sift if necessary and packaging in airtight containers.

In Cameroon, the main marketing outlet for cassava starch is the sector of cardboard-making industries, which has a potential market of 350-400 tons a year, for a unit purchase price standing around 500-550 CFAF/Kg .

In most of the cases, local industries are faced with problems of local supply of their raw material, competition of their finished products and narrowness of their market. Most of these companies are obliged to import their raw materials. Data collected from the Cameroonian custom duty for the first 9 nine months of the year 2007 carried out by IRPCM (initiative regionale pour la production et la commercialisation du manioc), evaluated the imported products to be 1808040 kg for a value of 1 215 904 332 FCFA.

Therefore, to be able to develop a larger share of the market for local cassava starch, we ought to look at the cassava starch value chain in Cameroon. The cassava starch process and the final product obtained have to be evaluated to come out with the characteristics of Cameroonian local cassava starch. It is in this vein that the present work was carried out, with the principal objective of evaluating the local cassava starch extraction process and proposing an improved financially profitable process. In order to do so, the first objective to accomplish was to carry out a survey that will permit to identify the local cassava starch producers of a particular region of Cameroon and to come out with the features of their production system. A process was then proposed and its financial profitability was evaluated.

CHAPTER TWO: MATERIALS AND METHODS

II.1 Study of the existing state

This consisted of carrying out a diagnosis of the local cassava starch producers. The population targeted in our study included mostly local cassava producers, who extract starch from cassava roots. The specific objectives of this part of our study was to

- Carry out a survey of local cassava starch producers in our target population.
- To observe the production of cassava starch in a particular locality.
- Analyse the process in the chosen locality. This in order to come out with the process yield, the yield of the most critical and difficult unit operations, and the time taken at each unit operation and for the entire process.

II.1.1 Area of study

The area chosen for our study was the central region of Cameroon. The choice made was based on the fact that the respondents of our survey had to be cassava producers. Statistics obtained from AGRI-STAT, 2012 reveals the central region as the area where cassava is the most cultivated in the country, with 1198080 tons cultivated in 2010. Therefore, a sample size of 33 producers was obtained from three subdivisions; Lekie, Mefou and Akono, and in Mefou and Afamba. A GPS of mark, GARMIN etrex 30 was used to help come out with the geographical location of the areas surveyed.

II.1.2 Survey

This was done using the survey-interview method. It involved meeting with local cassava starch producers at the level of two DONATA innovation platforms (at Nkong Abok and Batchenga), and with other producers in different localities of the central region. A series of questions from an elaborated questionnaire was addressed individually to each respondent, and their responses were recorded for later analysis.

II.3.2.1 The questionnaire

The questionnaire elaborated had four different parts.

- **Socio-economical features of the cassava starch producers.**

The first series of data collected concerned personal information of the respondents. Information collected from the respondents had to describe some socioeconomic characteristics of the respondents. This included; the name, age, gender, address and profession of the respondents. This section equally served to obtain information concerning; the origin of the process of the respondents, experience of the respondents in the domain of cassava starch production, and their knowledge on the different kinds of starch.

- **Raw material and other inputs used in the cassava starch extraction process.**

The next section of the questionnaire had to provide answers on the type of cassava used, the age of the cassava, the quantity of cassava used, the source of water, the quantity of water used and any other ingredient used in the process. The questions also helped reveal information on the storage mode of the raw material and other inputs of the process.

- **Characteristics of the unit operations involved in the cassava transformation process.**

The series of questions in this section helped to know how the respondents carry out cassava starch production. Information concerning the different unit operations, as well as the tools used, time taken and the number of persons involved in the unit operations was obtained in this section. The respondents had to provide answers concerning; the most critical and difficult unit operation, efficiency and ease of the tools used, sufficiency or insufficiency of the tools and persons involved in the process, the energy source used in the process, and description of the production site.

- **Properties, quality perception and end use of the final product.**

The last part of the questionnaire enabled the respondents to provide information on the quantity of starch they produced, the nature of the starch, the end use of the starch and how they measure the quality of the starch.

II.1.3 Brainstorming

In order to better know the difficulties and constraints of the producers, a brainstorming session was organised with 8 – 12 producers at the level of the Nkong Abok innovation platform. This contributed in taking the women's ideas on the main bottleneck of their production system and in general the obstacles of the starch value chain. Using the 5M method the constraints were then represented on an ISHIKAWA diagram.

II.1.4 Technological evaluation of the starch production system

Observation and measurements

To be able to come out with the main attributes of the women's starch process, we examined the process from beginning to end. This consisted of observing the entire cassava starch production process on site. This was done in the Nkong Abok locality, in the Mefou and Akono division. This permitted us to come out with a complete description of the process, and determine the time taken for the process, the process yield and finally the draw backs of the process. Three different productions were followed, from the first to the last step.

During the observation period, the mass of the cassava roots, water, intermediate products and the final cassava starch were measured using an electronic balance (mark: NAVAL BRAND and capacity 20kg). This was done at the beginning and the end of each unit operation of the process. Measurements were done on site and at IRAD Yaoundé. As mentioned earlier, the measurements carried out in IRAD were to confirm the measurements performed in the localities.

II.2 Physico-chemical characterization of the raw materials and final products of the process

II.2.1. Sampling of the cassava roots and starch

Two different cassava varieties were used in the process. For each variety a root was collected and brought back on the same day to the ENSAI Ngaoundéré school campus for laboratory analysis. Once the roots arrived in the laboratory, they were immediately cut into cassava chips and then dried and ground in powder form. The varieties were then kept separately in a closed polyethylene plastic and then stored in a cupboard in the laboratory. A quantity of cassava starch (varying between 0.5-1kg) obtained from the three different variety were collected. The cassava starches collected were kept in air-tight polyethylene plastics and stored in a closed dry cupboard. The analyses were carried out in the ENSAI Physico-chemical laboratory in order to determine the various parameters listed below:

II.2.2 Physico-chemical analysis

II.2.2.1 Measurement of dry matter and water content

The dry matter content of the cassava roots and starch was determined by the method put in place by the AOAC (1990).

- **Principle**

The method is based on the measurement of the loss of water (dehydration) after drying at 105°C for 24 hours (until a constant mass is attained).

- **Procedure**

2.5 g of each different sample (cassava chips and starch) was weighed using an electronic balance and placed into a nacelle. The empty nacelle was weighed before introducing the samples and the mass of the nacelle was recorded. Then, into a desiccator the sample contained in the nacelle, was placed in a desiccator. This served to avoid the sample to reabsorb moisture. The sample contained in the desiccator was transported to an electronic oven. The sample was kept in the oven set at 105°C, and left there until a constant mass was attained, that is for 24 hours. This was repeated trice for each different sample. After 24 hours, the samples were removed from the oven, and placed in the desiccator. This served to cool the samples and to avoid them to reabsorb moisture. After which, the samples were weighed on the electronic balance and their masses were recorded. The dry matter content was expressed as illustrated in appendix 5.

II.2.2.2 Measurement of 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.

- **Preparation of the starch standard curve**

0.5 g of the standard 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 of distilled water containing 0.5g of the standard 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 standard 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 standard 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.

- **Preparation of the samples for starch and amylose content measurement**

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 0.5ml of distilled water 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 described 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. The table for the quantities used in the measurement are presented in appendix 6.

II.2.2.3 Measurement of ash content

The ash content of the cassava powder and cassava starch was measured using a modified 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 at 105°C in a muffle furnace until it attains a constant weight.

- **Procedure**

A crucible was washed and weighed and its mass noted (M0). Then, 2.5g (M1) of each sample was weighed into the crucible and placed in a desiccator. The crucible containing the starch was then placed in the muffle furnace set at 550°C and incinerated for 6hours, until light grey ash was obtained. The crucible was then removed from the muffle furnace with the aid of pincers and cooled in a desiccator. The crucible was then weighed when room temperature was attained and the masses recorded (M2). The procedure was repeated 3 times for each of the sample. The expression of the ash is presented in appendix 10.

II.2.2.4 Measurement of the water absorption capacity and solubility index

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

- **Procedure**

2 g (M0) of each starch samples were weighed into separate centrifugal tubes. The empty centrifugal tubes were weighed before and the masses recorded (W0). 25 ml of distilled water was then introduced into the centrifugal tubes containing the samples. Using our hands the test tubes were agitated for 2 minutes and allowed to stand for 15 minutes. The set up was then centrifuged at 3500 rpm for 10 minutes at room temperature. The supernatant was then discarded and the wet sediment contained in the centrifugal tube was weighed and the mass recorded (W1). After which, the wet sediment was introduced into an empty nacelle. The empty nacelle was weighed previously and masses recorded (N0). The nacelle containing the wet sediment was dried into an electric oven at 105°C for 24 hours. The procedure was repeated 3 times for each of the samples. After 24 hours, the dried samples + nacelles were weighed and the masses collected (N1). The formula used to express the results is found in appendix 11.

II.2.2.5 Measurement of pH and total acidity

This experiment was carried out following the method described by Tetchi et al., 2012.

- **Principle**

This method measures the total organic acidic (principally lactic acid) present in our samples. This is a titration method that gives the concentration of NaOH that will neutralise the H^+ ions of the organic acids contained in our samples. The pH gives the amount of H+ ions present in all our samples.

- **Procedure**

3g (M0) of each cassava starch sample were weighed into separate individual tubes. 27ml of distilled water were then introduced into the centrifugal tubes. Then, using an electric arm agitator, the solution in the centrifugal tubes was agitated. After which, the solution was centrifuged at 3500rpm for 10minutes. Then using a pH meter, the pH of the different samples was read. The supernatant was then collected and titrated using the NaOH solution. The titration was stopped once a pink coloration was observed. This procedure was repeated trice for each sample and the calculation to obtain the results is presented in appendix 12.

II.2.2.6 Measurement of the cyanide content

To determine the cyanide content in our samples, we used a modified method described by Jackson,(1967).

- **Principle**

This method is based on the reaction of evolved hydrocyanic acid with potassium hydroxide to form potassium cyanide, which then reacts with sodium picrate, forming a red-coloured compound. The colour intensity is measured at 520 nm.

- **Procedure**

Extraction of starch cyanide

2.5g of each sample (cassava and starch) was weighed into a glass container. 62.5ml of distilled water was introduced into the glass and the solution was left to stand for 4hours. After the 4hours, the solution was introduced into a round bottom flask, and 1.25ml of chloroform was pipetted into it. The round bottom flask was then distilled and the distillate was collected in a beaker containing 2.5ml of 2% KOH. When 12-15 ml of the distillate was collected, the distillation was stopped and 10ml of the distillate was pipetted and transferred into a measuring cylinder.

Quantitation of total cyanide

The measuring cylinder was filled up to 25ml using distilled water. Using a pipette 5ml of solution was transferred from the measuring cylinder and placed into a test tube. Then 5ml of picrate acid was added to the 5ml solution in the test tube. This was done for three repetitions. A blank solution was prepared using distilled water instead of the diluted distillate solution. Then the test tubes containing the sample solution and the blank were heated in a boiling water bath for 5 minutes. After which the solutions were left to cool and then read at 520nm. The preparation of the standard curve is presented in appendix 13.

II.2.2.7 Determination of the gelatinization degree

The gelatinization degree of our starch samples was carried out using the method of Cabrera *and al* (1984)

- **Principle**

The principle of this method is based on the reaction of amylose with lugol at 650nm. When starch is heated at temperature above 50°C in the presence of excess water, amylose will leach out from the starch granules. The amount of amylose that is leached depends on the degree or extent of gelatinization. This amount of leached amylose is quantified using a spectrophotometer.

- **Procedure**

Measurement of complete gelatinization

Into a test tube, 0.1g of each starch sample was weighed with the aid of an electronic balance. 10ml of distilled water was then transferred into the test tube using a pipette. The test tube was then placed in a water bath, at 100°C for 30 minutes. The test tube was then removed from the water bath and left to cool. After which, the solution in the test tube was centrifuged at 3000rpm for 20 minutes. Then 1ml of the supernatant was then collected and transferred into another test tube. 2ml of lugol solution diluted 100 was added to the solution in the test tube and it was ready to read using a spectrophotometer. For the blank, the 1ml of supernatant was replaced with distilled water. The procedure was repeated with two more trials, to give a series of 3 trials in all.

Measurement of the degree of gelatinization at different temperatures

In order to determine the degree or extent of gelatinization, the same procedure was repeated as in the experiment described above with some modifications. The temperature used here varied from 50°C-100°C, with a temperature gap of 10°C. The heating temperature was 10minutes instead of 30minutes. The procedure was then carried out in the same manner as described above. The method used to express the results is found in appendix 14.

II.2.2.8 Determination of the shape of the starch granules

The shape or form of the starch granules obtained from our two pure varieties was observed under a light microscope.

- **Procedure**

A small quantity (a stiff) of the starch sample was placed on the microscopic slide. 2 drops of lugol diluted 10 times were added onto the starch samples. The starch sample was then observed under the microscope at magnification X100. Using a digital camera, snap shots of the starch granules observed under the microscope were done and the pictures were taken.

II.2.2.9 Measurement of the pasting properties

The pasting properties were determined using a rapid visco analyser (RVA) (Perten instruments, Australia).

Principle

The Rapid Visco Analyser (RVA) is a rotational viscometer that continuously records the viscosity of a sample under conditions of controlled temperature and shear. The ability of the RVA to suspend samples in a solvent, maintains those samples in suspension throughout the test, and applies an appropriate amount of shear to match processing conditions. During a standard starch analysis, the starch is heated in an aqueous environment. The starch granule imbibes water and swells, the internal crystalline structure melts (gelatinization), the granule itself breaks down and a continuous gel forms. The viscosity changes produced by heating and cooling starch in water generally provide a similar characteristic pasting curve.

Procedure:

This was done on 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) and Breakdown (BD), Peak viscosity (PV) and pasting temperature. From these parameters another parameter was calculated: Disintegration ratio (DR) which is the ratio of BD and PV. The table of the different parameters for the measurement is found in appendix 15.

II.3 Financial evaluation of the process

A financial evaluation of the process was also done in order to determine the profitability of the women's process. The gross profit of the process was used as profitability indicator.

II.4 Analysis of the data

The results obtained from the survey were analysed with the software: sphinx Lexica-V5 and Microsoft excel 2010. The results obtained from the physico-chemical analysis were analysed with statgraphics plus 5.0 and sigma plot 11.0 was used to plot the graphs.

CHAPTER THREE: RESULTS AND DISCUSSION

III.1 Survey: Cassava starch production system in the central region of Cameroon

III.1.1 Socio-economical features of the producers

Extraction of cassava starch is mainly a woman's activity. Figure 6 shows that, in this region of the country, 94% of the activity is carried out by women as shown by figure 6. 95% of these women are above 40years of age. This implies that most of the working force is in the ageing group. The youth do contribute very little in the activity. This could be related to the fact that most of the young women and girls live in the urban towns.

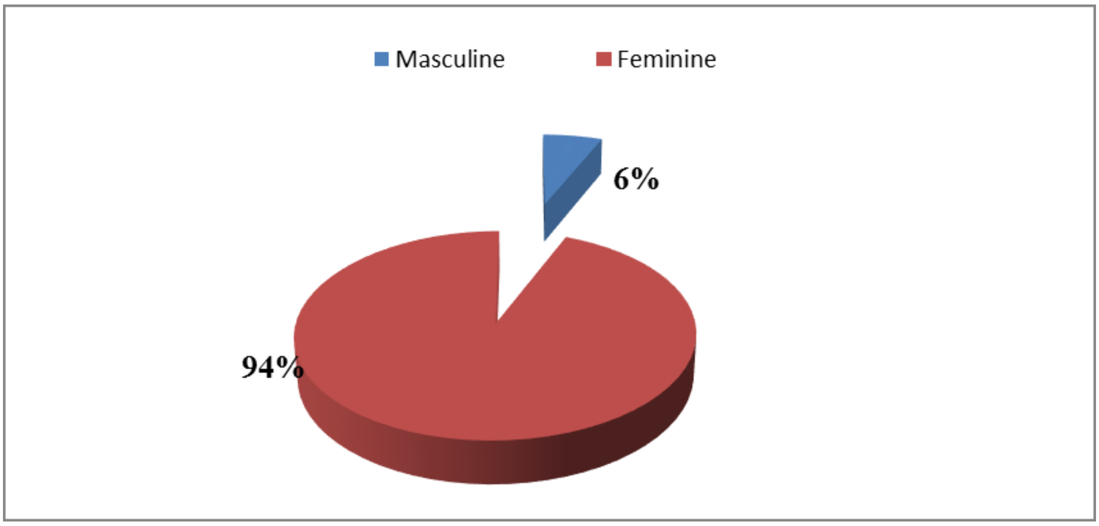


Figure 6: Gender distribution of the respondents

The main occupation of the women is agriculture, with 45.16% of the women involved in agricultural activities. It is their prinicipal source of income. The extraction of cassava starch in this region has last for less than 10 years. Table 6 indicates that 87.1% of the respondents have less than 10 years of experience in the activity. This explains that the activity is not an ancient practice. Table 7 presents the origin of the process used by the producers. The survey reveals that 74% of the respondents inherented from the process technique through training or formation (table). This point adds to the fact that the process technique is not that old. Hence cassava starch extraction process is not native to the studied population.

Table 6: Occupation of the female respondents and their longevity in cassava starch processing

Variable	Responses	Primary activity	Secondary activity	Years of experience
Gender	Feminine	Agriculture 45,16%	Agriculture 45,16%	< 10 years 87,09%

Table 7: Origin of the process used by the respondents

Characteristics	Responses	Percentage (%)
Family heritage	4	12,10
School	2	6,10
Yourself	3	9,10
Training	26	78,80

The actors in this region have very little knowledge on the different starch forms. For the respondents, two types of starch forms do exist; powder and liquid native starch. All the respondents do recognise powder native starch as the main starch type. Of the respondents aware of more than one starch form, 44.4% acknowledge the existence of liquid native starch. This implies that native powder starch is the predominant starch type in the region. In this population none of the respondents did mention knowledge of modified starch products. The limited knowledge on the various starch points out the little experience in the domain of starch processing.

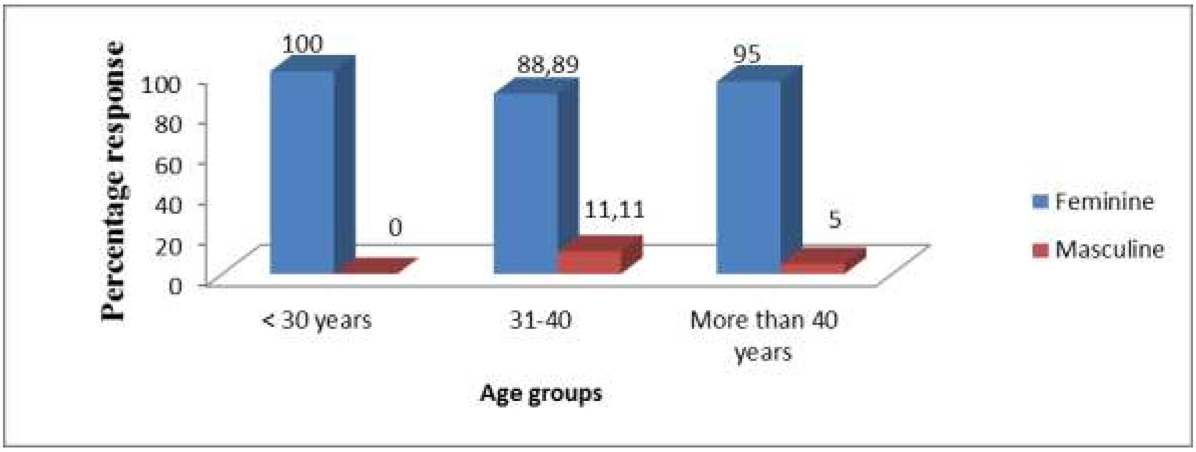


Figure 7 : Gender distribution according to age groups

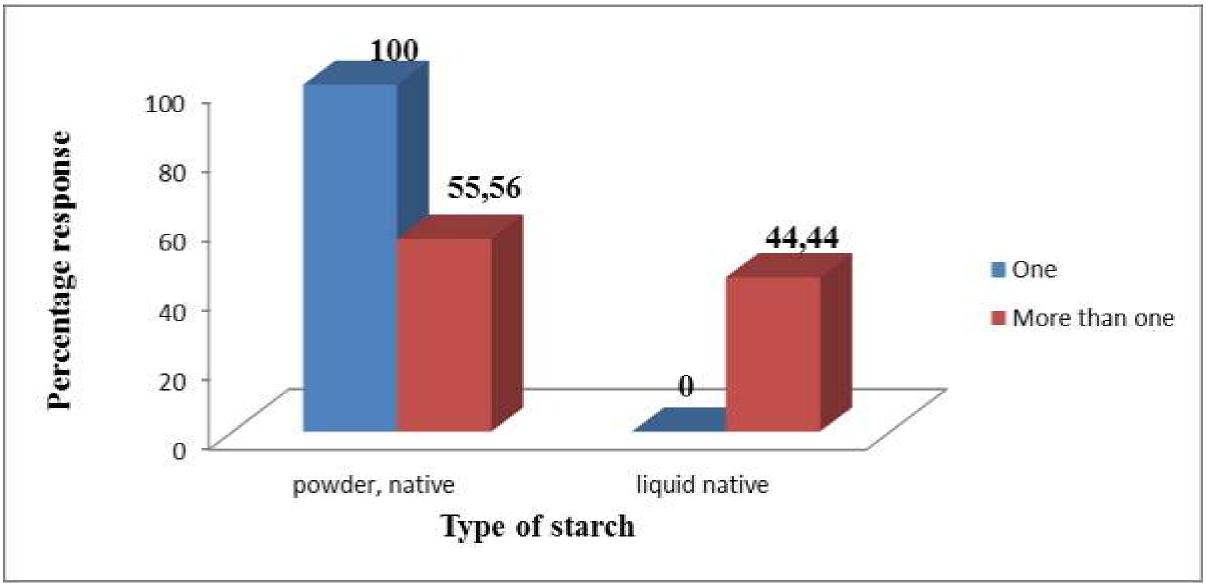


Figure 8 : Respondents knowledge on the different types of cassava starch

III.1.2 Raw material and other inputs used in the cassava starch extraction process

Cassava and water are the only raw material used in the process. The variety of the cassava is differentiated in terms of its cyanide content; bitter cassava for high cyanide content cassava and sweet cassava for low cyanide content cassava. The source of the cassava varieties may be local or improved varieties. Figure 9 shows that 58% of the cassava used is the sweet variety type. The source of the cassava is mainly from the localities as represented by 67% of the responses in the figure 10.

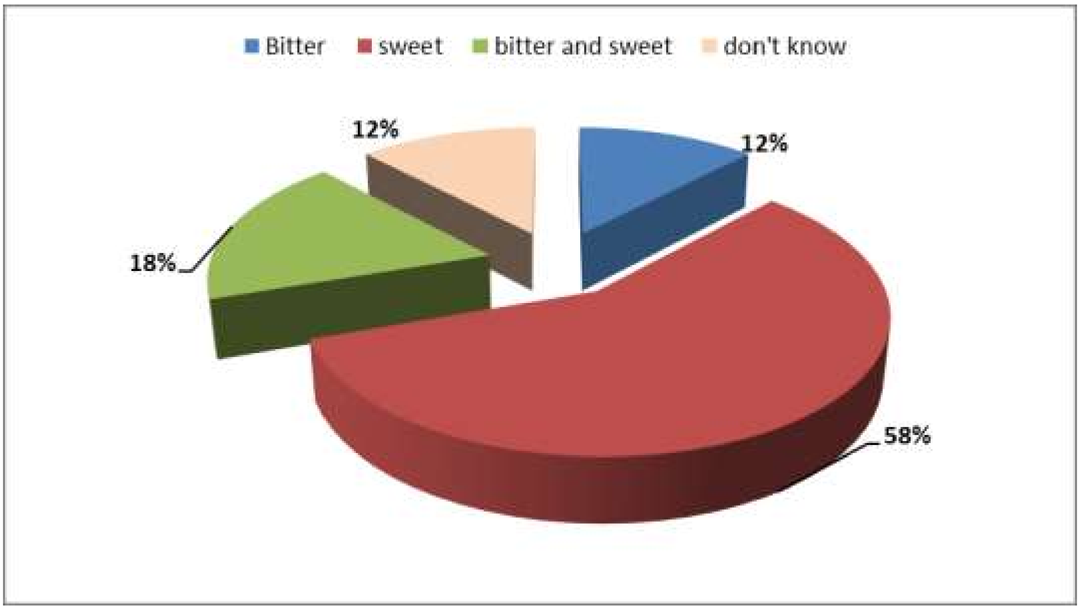


Figure 9 : Distribution of the type cassava variety used by the respondents

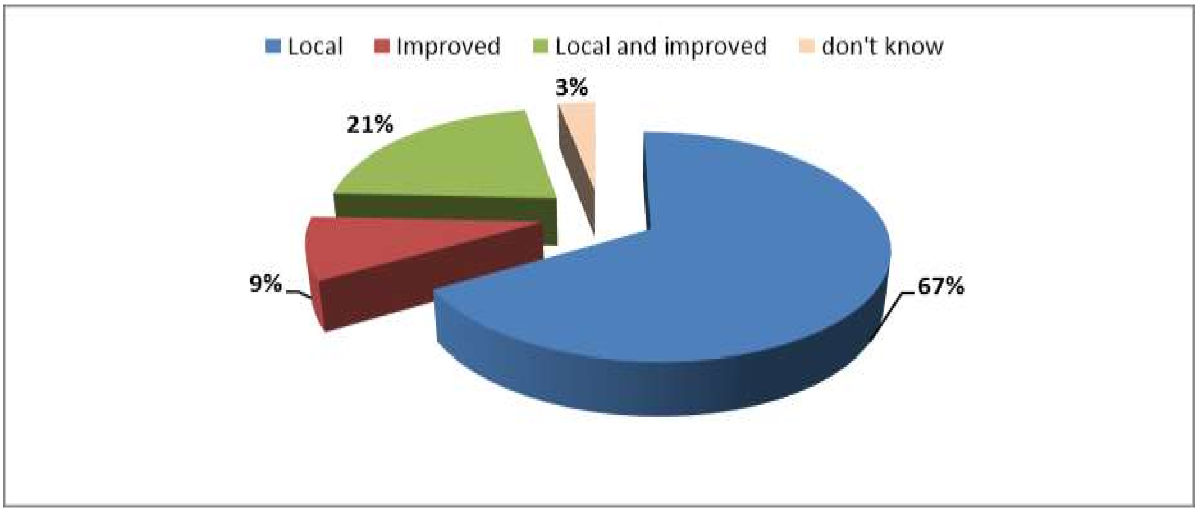


Figure 10 : Source of the cassava variety used by the respondents

Figure 11 reveals that among the 67% of respondents that obtain their cassava starch from local sources, 81.1% of it is the sweet variety type. Among the 9% of the actors that obtain cassava from improved sources, 100% (all of them) of it is the bitter variety. The bitter cassava is mainly obtained from improved varieties form research institutions mainly IRAD and IITA Cameroon. This therefore means that the cassava starch producers do not use the bitter varieties from their own locality. Hence we could therefore conclude that, the producers use mainly their own sweet cassava varieties, but prefer to use few bitter varieties from other sources than their own local source. For those who obtain their cassava from both local and improved sources, 57.1% of them do use both varieties (bitter and sweet). Hence this means that of those respondents how use both cassava varieties, they obtain the cassava both from the local sources and IRAD or IITA Cameroon.

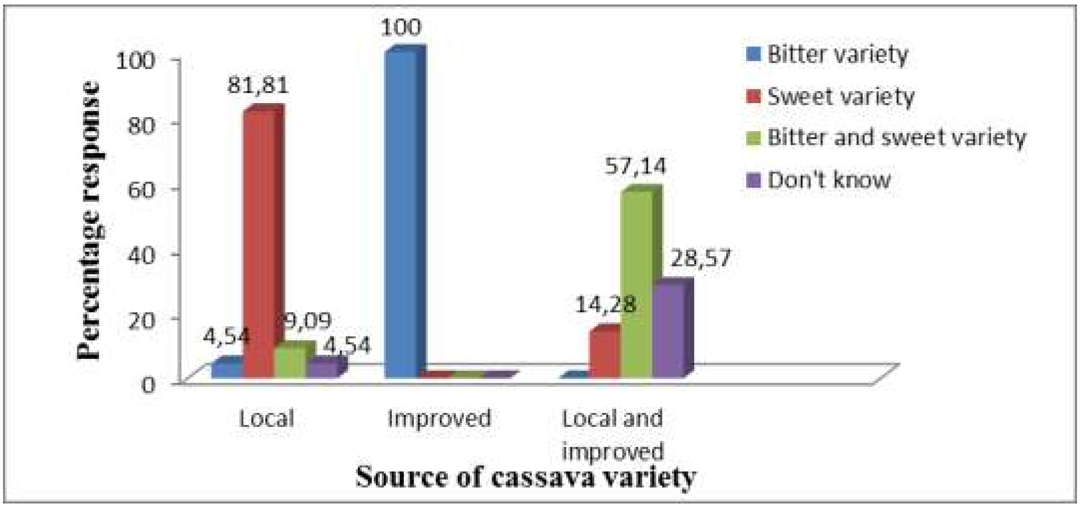


Figure 11 : Choice of the cassava variety used by the respondents, according to the source of the cassava variety

Figure 12 presents the amount of cassava that enters the process. 54.6% of the respondents do not know the quantity of cassava they used in the process. This implies that the majority of the producers have a limited mastery of the extraction process. The limited knowledge on the cassava used reveals the lack of a weighing machine as one of their equipment. Figure 12 also revealed the different local measurement units. They mostly use what they call baco bags, and baskets to estimate the quantity of cassava used.

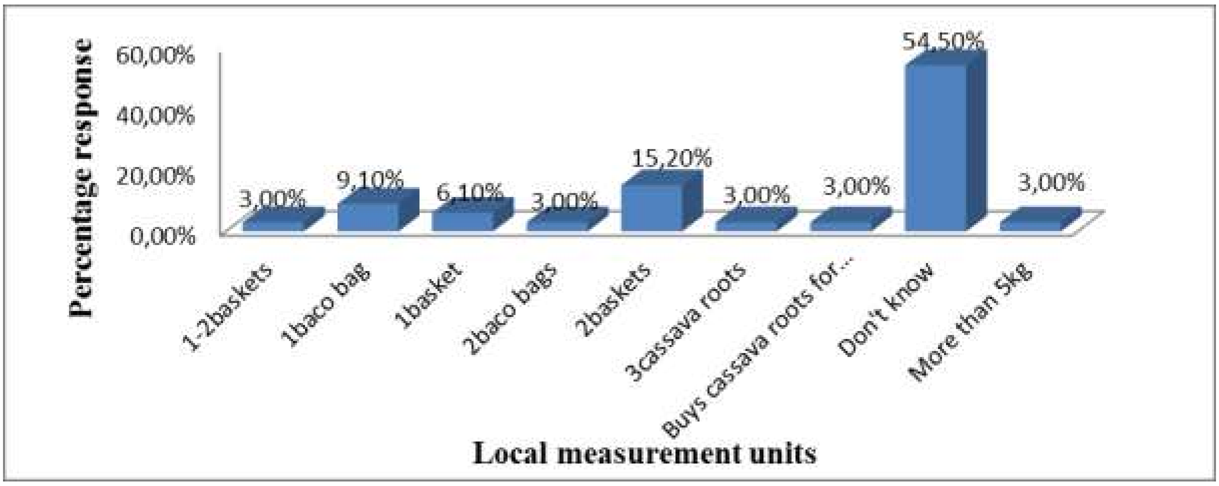


Figure 12 : Quantity of cassava used for by the respondents in terms of local measurement units

Figure 15 shows that, the main age of the cassava used in the process is found between 11.5-17.5 months. 45.50% of the responses obtained correspond to this age group. However, the two principal age groups for the cassava used fell between 5.5- 17.5 months. 72.8% of the responses obtained correspond to this age group. Hence, this reveals there is no fixed age for the cassava used in their extraction process and therefore it indicates that the people consider the maturity age for the cassava they use in the starch production to be between 5 and 18 months.

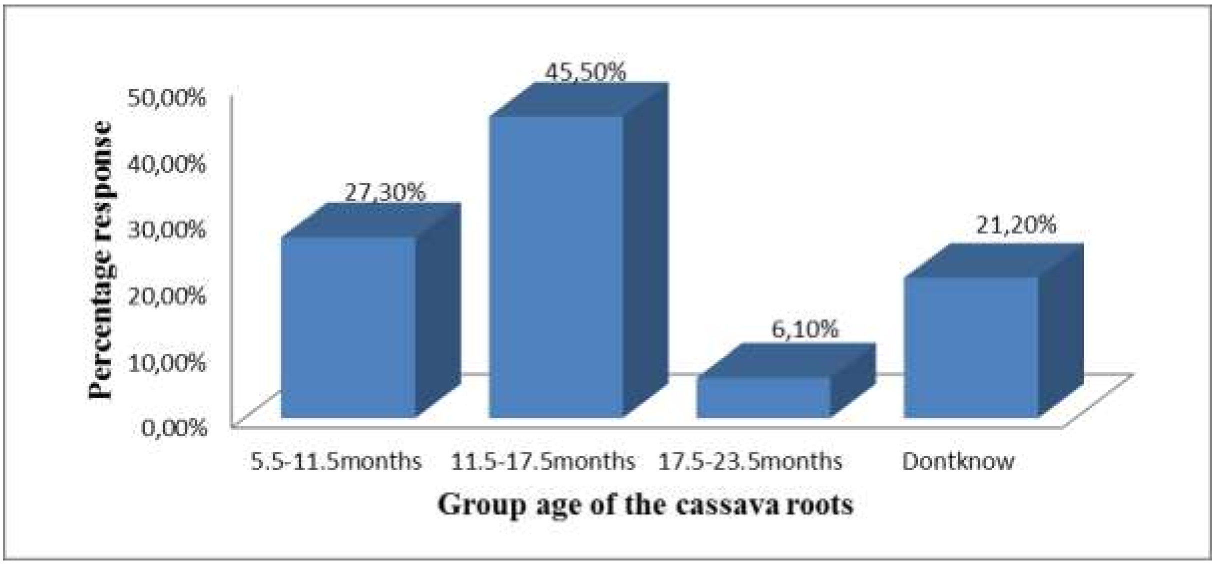


Figure 13 : Age at which the respondents harvest their cassava for the extraction process

The main source of water is from water-springs and wells. Figure 16 represented below shows that 72.8% of the population obtain their water from those two sources, with 46.9% of the respondents using water-springs. This could be related to the fact that in rural areas, CAMWATER does not provide adequate water to this sector of the country. Hence, the people obtain their portable water which they use in the production process from springs built mostly by non-governmental organisations (NGO's) or private companies. Figure 15 presents the mode of water acquisition from the different water sources. 81.80% of the respondents go ketch their water from the springs during the process. This could explain that during the process, the actors give preference to a fresh source of portable water, than their own water reserves. This also reveals the time consumption and tediousness of the process, as they have to go ketch water from the water spring.

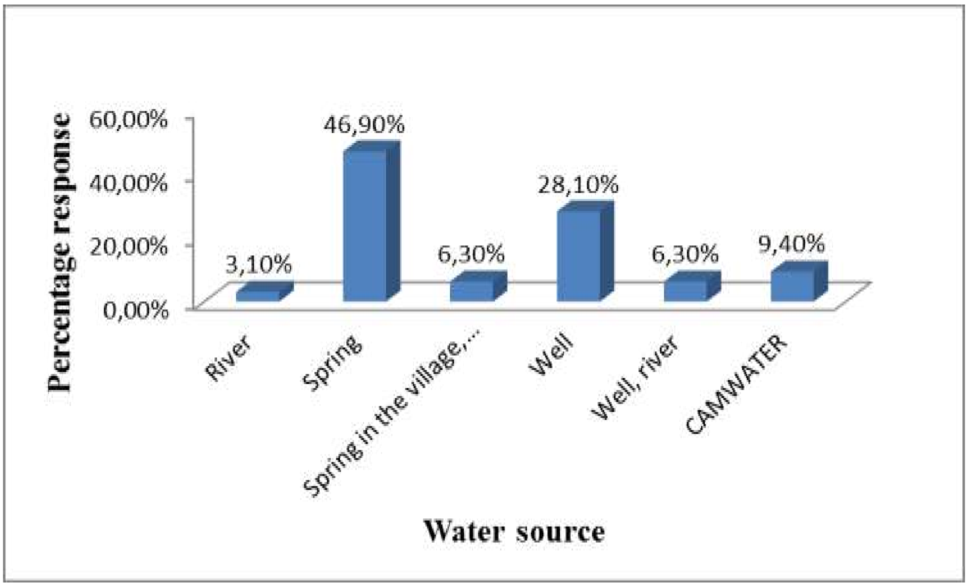


Figure 14 : Respondents source of water used during the extraction process

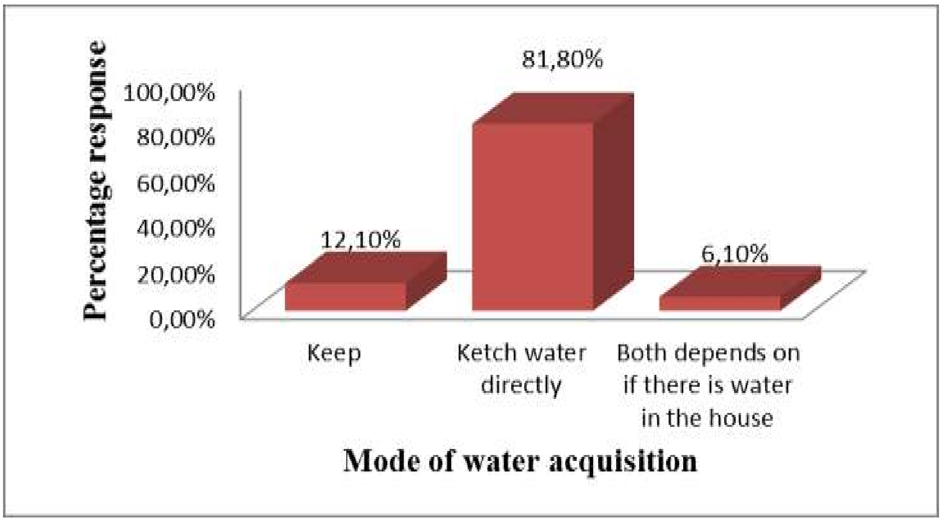


Figure 15 : Respondents acquisition modes of the water used in the process

The global quantity of water used in the process by the actors is not clearly known. The answers obtained from the respondents provided an idea of the quantity of water used for a complete process. Table 8 shows the average amount of water used in the process and this corresponds to 24litres per production. However, as mentioned previously, the quantity of cassava used in the process is not known. Hence, we could conclude only on the amount of water used during the complete process for quantities of cassava that are unknown by the actors.

Table 8: Average amount of water used per respondent in the entire extraction process

Unit amount of water/production	Number of respondents	Total litres of water/ production
1,5	1	1,5
100	1	100
10	2	20
15	3	45
45	1	45
40	1	40
1	1	1
20	6	120
30	2	60
Total	**18**	**432,5litres**
Mean		**24,02litres**

III.1.3 Characteristics of the unit operations involved in the cassava transformation process.

The unit operations in the process vary very little from one respondent to the other. In a chronological order, the first three unit operations are; peeling, washing and rasping, and these are principally the same for every respondent as indicated by the percentage responses in figure 16 below. As from the fourth unit operation variations in the process occurs, but the general process may be described to be carried out in 7 steps as shown in figure 16. The 8th step may not be really considered as a principal unit operation, as only 44.4% of the respondents do package the final product.

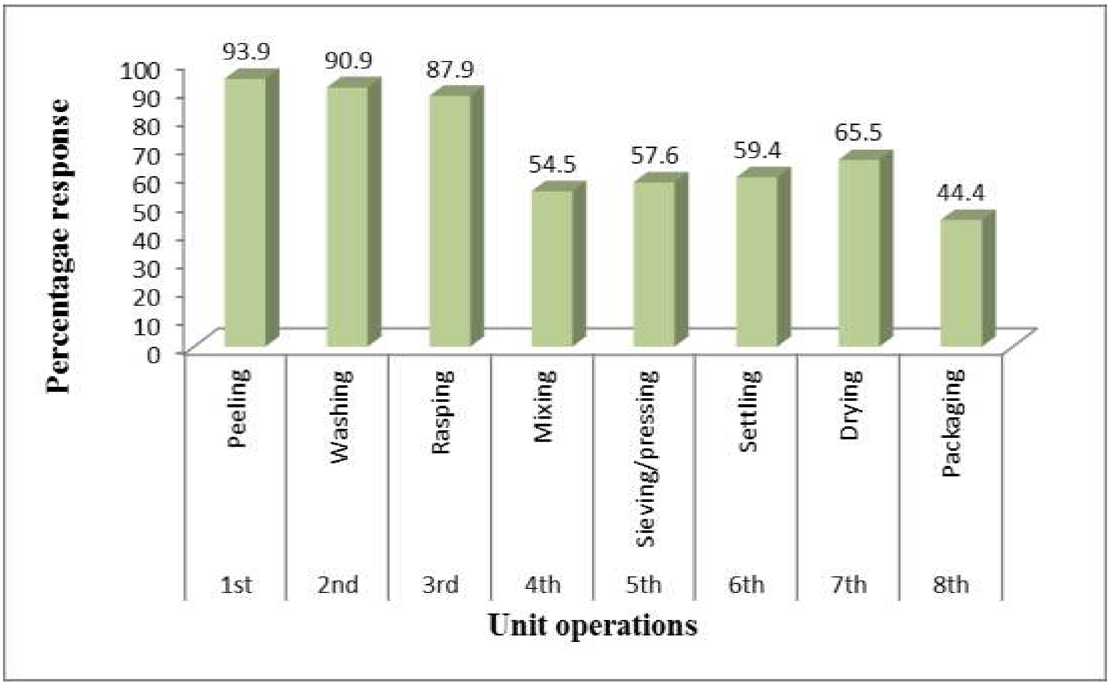
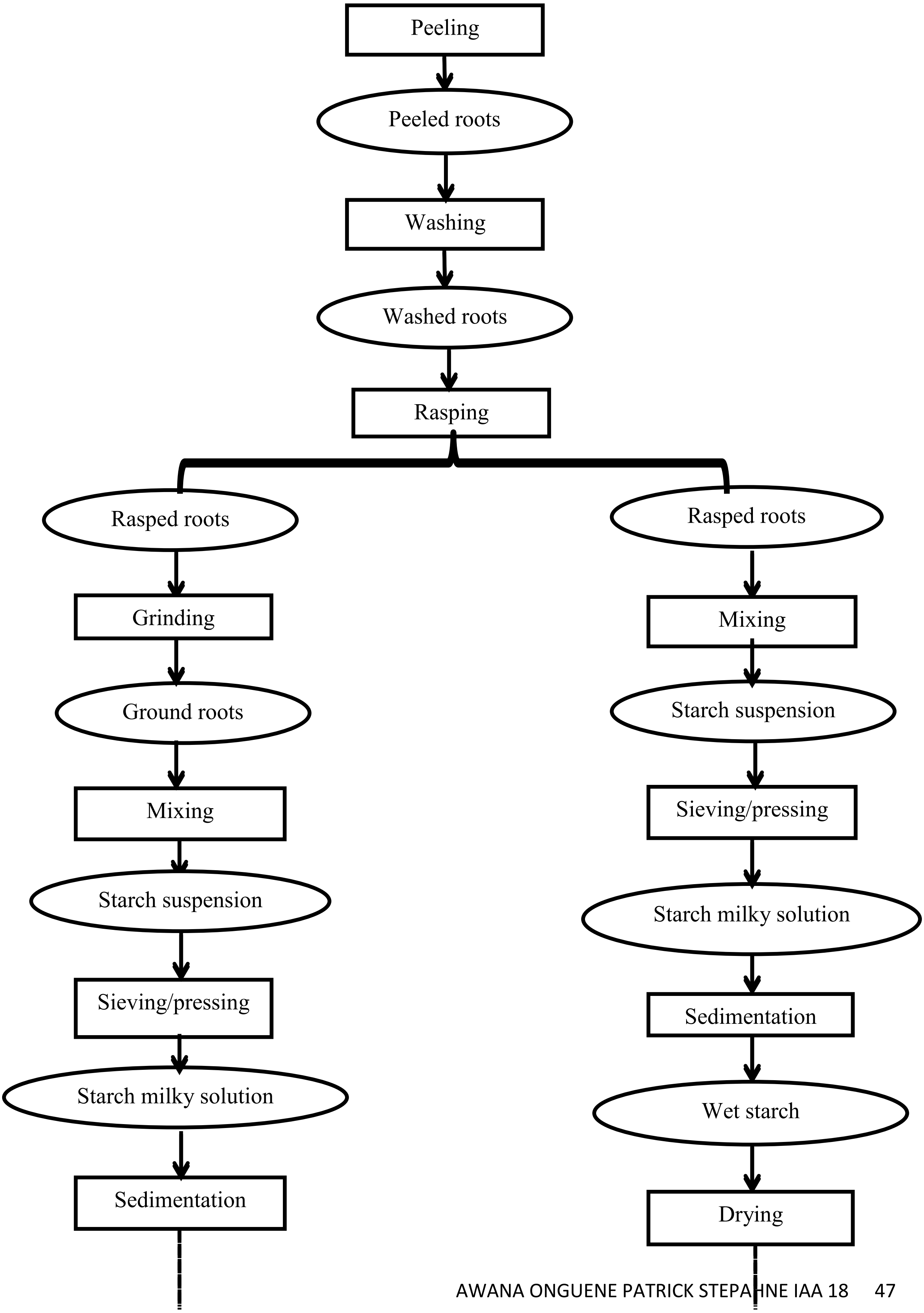


Figure 16 : The main unit operations involved in the transformation process of the respondents

However, the extraction process is not carried out the same way for all the respondents. Figure 17 below shows the variation in the cassava extraction process. It reveals that there are two different extraction processes in the surveyed region.

As in the case of the unit operations, the tools used are practically the same for each respondent. The tools used by the respondents are presented in Figure. The tools used are mainly kitchen utensils. This reveals the production system to be traditional with very little mechanized equipment, or equipment that do not require a source of energy. This therefore explains the nature of the process to be labour intensive, since every unit operation is carried out manually with non-mechanized equipment. This therefore matches with the fact that the producers do not carry out the extraction process individually.


Peeling
Peeled roots
Washing
Washed roots
Rasping
Rasped roots
Grinding
Ground roots
Mixing
Starch suspension
Sieving/pressing
Starch milky solution
Sedimentation
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Starch milky solution
Sedimentation
Wet starch
Drying

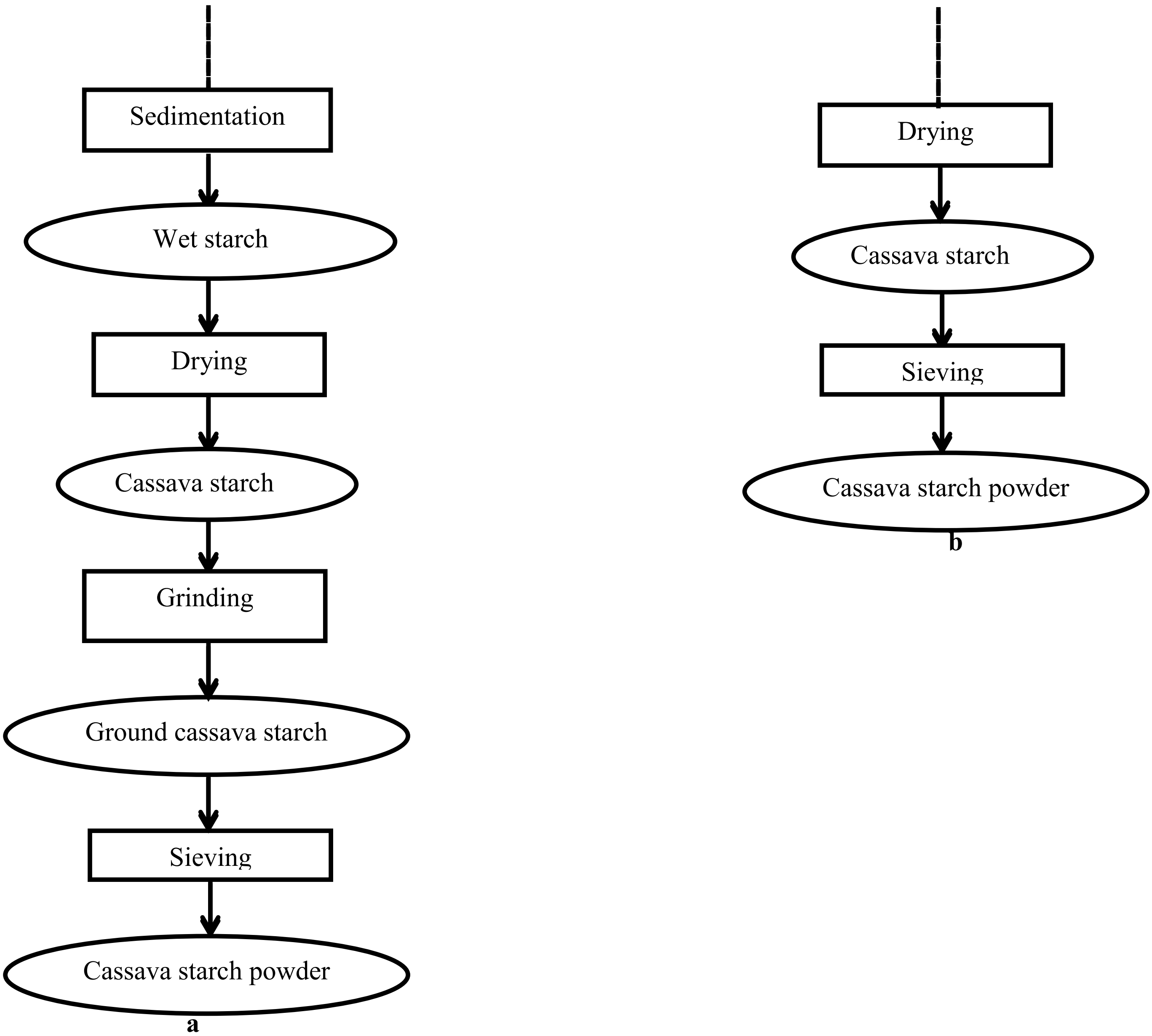


Figure 17 : Cassava starch extraction processes as described by the respondents

57.6% of the respondents organise themselves into groups with at most 10 people involved in the entire process as shown in figure 19. The producers prefer to associate themselves to obtain the final product.

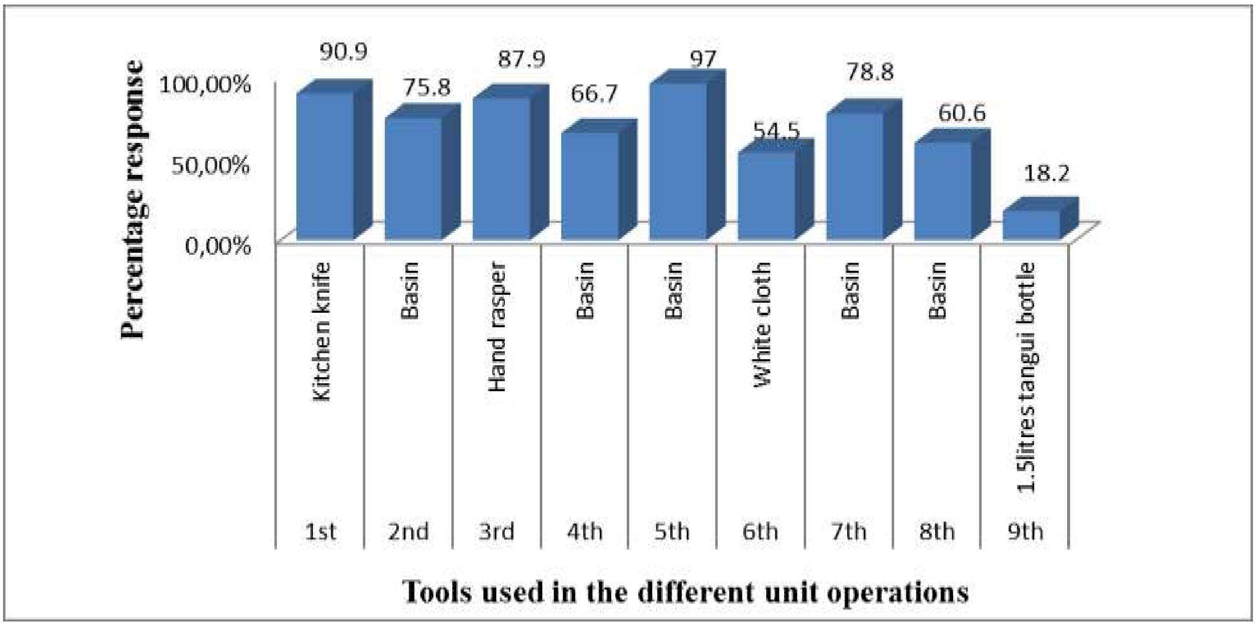


Figure 18 : The principal tools used in the extraction process of the respondents

During the production of cassava starch there some unit operations which the producers single out as being critical. Critical unit operations are those which if not carried out properly, they will influence the desired quality of the final product. Table 9 gives information on these unit operations. From table 10, we could say that, if the cassava starch is not dried properly it will influence on the quality of the product negatively. The same for the sieving/pressing unit operation, which if not done properly will lead to undesired characteristics of the final starch product.

Table 9: Critical and difficult unit operation in the cassava extraction process

Critical unit operations	Response	
	Number	Percentage (%)
Sieving/pressing	11	33,30
Drying	12	36,40
Difficult unit operations	**Response**	

	Number	Percentage (%)
Rasping	18	54,50
Sieving/pressing	6	18,20

Table 10 also reveals that, 60.60% of the population considers the process difficult to carry out. 42.40% of the population believes that the labour force involved is not sufficient. From figure 19 below, 67.85% of the respondent process cassava starch in groups of 10 people. Hence we could say that the process is a strenuous and demands an important labour force number. Hence, the process is not efficient.

Table 10: Respondents perception of the working conditions of the cassava extraction process

Responses		**YES**	**NO**	**Don't know**
Variables	Sufficient labour force	Number: 16 Percentage: 48,50%	Number: 14 Percentage: 42,40%	Number: 3 Percentage: 9,10%
	Ease of the process	Number: 11 Percentage: 33,30%	Number: 20 Percentage: 60,60%	Number: 2 Percentage: 6,10%

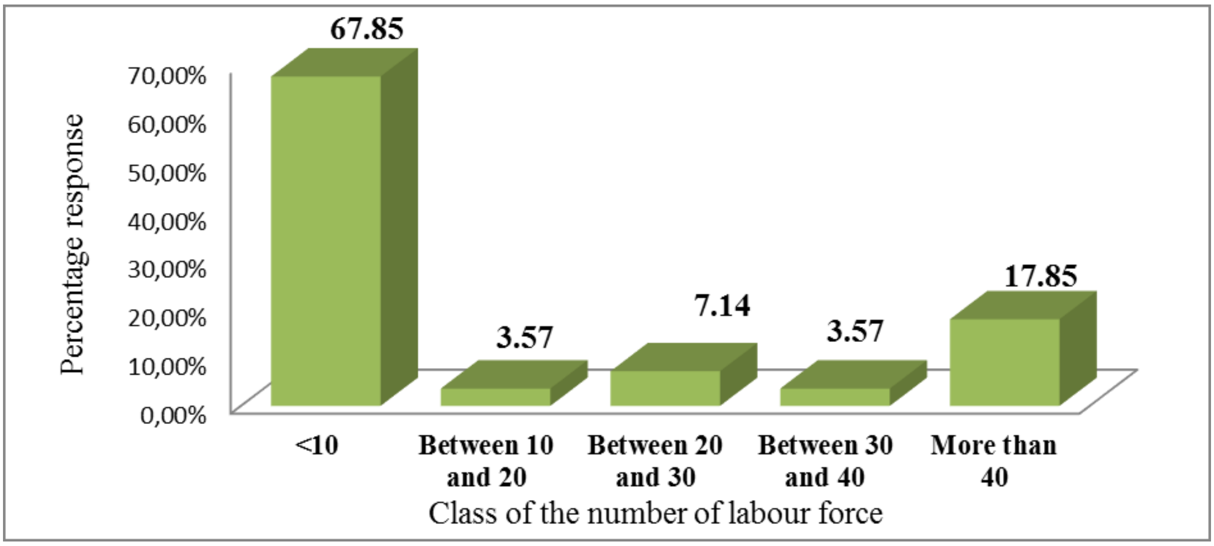


Figure 19 : Distribution of the number of labour force involved per extraction process

III.1.4 Properties, quality perception and end use of the final product.

Table 11 presents the main properties that characterise the cassava starch produced by the respondents. All the producers deliver their final product as native powder starch. Only one producer does produce liquid native cassava starch. As is the case for the raw material used, the final product is not measured most of the times. 65.62% of the respondents do not know the quantity of cassava starch that they produce. This adds once more to the fact that there is a lack of weighing balance as one of their equipment. The cassava starch produced in this region is mainly for household composition or use. The producers mostly use the starch for laundry proposes.

Figure 20 reveals the various criteria used to appreciate the quality of their cassava starch. Most of the respondents use the cassava starch in washing their clothes. It is after washing these clothes with cassava starch that they do perceive the quality of the starch they produce. For most of the producers (39.40%), a good quality starch is one that gives a cloth with a firm nature after washing. However, other quality criteria do exist such as; texture of the cassava starch. For 18.20% of the producers, the starch has to be well dried and have a dusty nature. Another quality has to be the colour of the starch at sight. The starch has to be very white as described by the producers. This implies that the producers do have a method of determining the quality of their cassava starch.

Table 11: Some features of the cassava starch produced in the area of survey

Nature of the cassava starch	**Response**	
	Number	**Percentage (%)**
Powder	33	100
Liquid	1	3
Measurement of cassava starch	**Number**	**Percentage**

Yes	11	34.37
No	21	65.62
Use of cassava starch	**Number**	**Percentage**
Household use	33	100
For sale	10	30.30

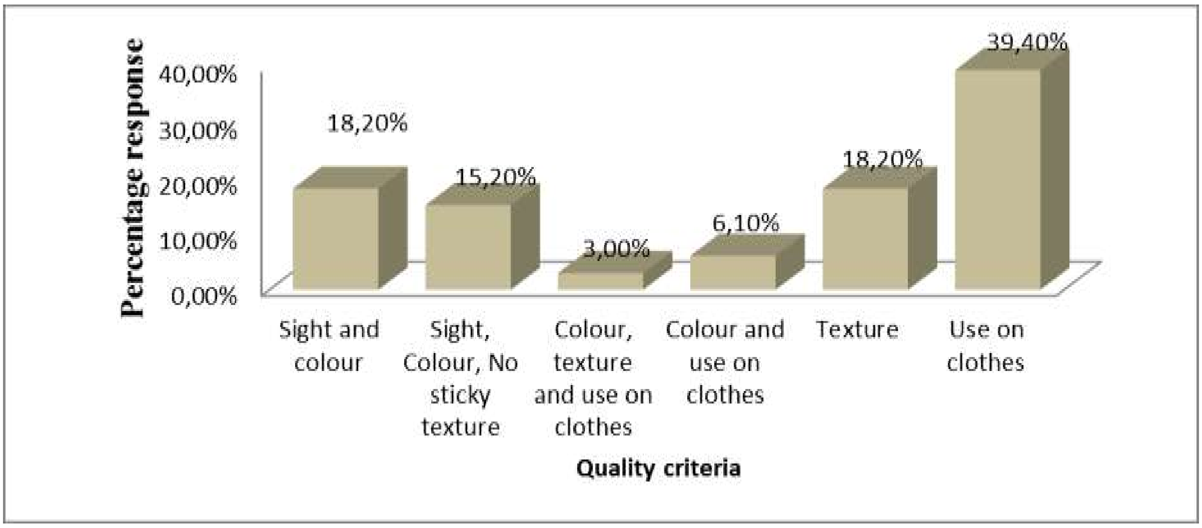


Figure 20 : Quality criteria for cassava starch

To conclude from this survey, cassava starch production in the central region is not a well-developed activity in the region of Cameroon. The actors involved are mainly women of more than 40 years of age. For these women they try to valorise the cassava that grows easily in the farms and also try to gain some money from it. For this reason, the women use the cassava starch first for household purposes and afterwards, they try to make some money from it. The men and the youths do not participate a lot to contribute to this activity. The process is laborious, completely manually and it consists principally of 7 unit operations. The limited knowledge on the amount of inputs and outputs of the process, points out its non-standardized nature. The population do not count much on cassava starch as a solution to their financial problems.

III.1.5 Limitations of the survey

The survey carried out was supposed to enable us to come out with the starch value chain in Cameroon. But this was limited by the lack of participation from the starch users. Most of the dry cleaners showed reluctance in revealing information concerning the starch they use. Only one industry accepted to answer to the questionnaire prepared for them. However, if we had to propose the cassava starch value chain in the central region of Cameroon it will look as the figure represented below. The women are at the centre of the chain. They cultivate the cassava, process it, sell it, and they are still the ones who mostly buy or use it.

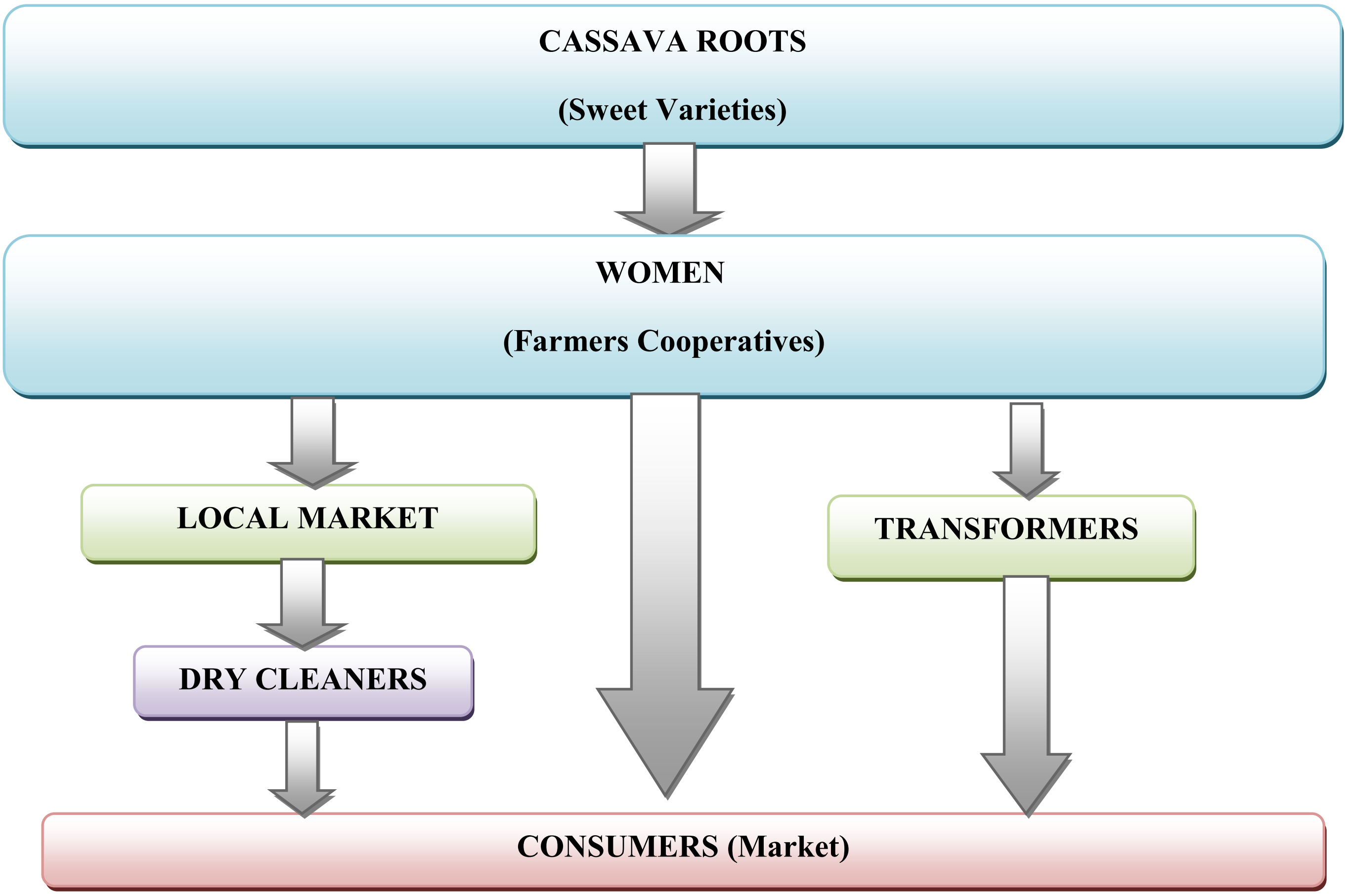


Figure 21 : Cassava Starch Value Chain in the Central Region of Cameroon

III.2 Brainstorming and observation

From the brainstorming, the main difficulties encountered by the women of the Nkong Abok locality are presented in figure 22 below.

III.2.1 Classification of the constraints of the production system

✓ **MACHINE**

The main constraint encountered by the women in Nkong Abok, during processing of their cassava is that of lack of equipment. The women lack the basic tools used in processing cassava starch. This puts them in a situation where they have to group themselves in order to produce starch, be it in small or large quantity. This implies that it is impossible for a single woman to produce cassava starch, most especially if she wishes to produce in large quantity.

The women do not have the adequate tools. In order to solve for the problem of insufficient tools, the women are forced to adapt some tools for a particular unit operation. For example, during pressing and sieving the women use a cloth they consider clean for the sieving process. But this is not actually a tool adapted for this operation. The women use principally kitchen and house utensils they possess to carry out the starch production.

✓ **MATERIAL**

The distances to the farms are quite important, and the means to access the farms is solely by walking. The women find themselves walking through a distance of between 1 – 10km. This implies walking for about 30minutes - 2hours to reach their farms. This renders transportation of the cassava roots to be tedious. Hence this causes access to their raw material difficult. Access to portable water is not common. The unique source of portable water is from water-springs. This water springs are not at proximity to their houses, and hence to their production site. Therefore portable water is a limiting factor to their process. The cassava used as raw material is not well defined. There is no specific cassava used for cassava starch production. The cassava used in the production is that used for the production of different cassava products. Hence the raw material used for cassava starch competes with other cassava products.

✓ **METHOD**

The method of processing cassava starch is completely manual, with no mechanical or automated machines. This renders the process very laborious and at a certain point even risky. The method used implies that the process has to be completed the same day the cassava is harvested from the farm. But then, the method is time consuming, and long to complete. This is favoured by lack of mechanized equipment and insufficient man power. This leads to less participation of the women, as most of them do not always have the patience of completing the process till the end.

The method is not a standard one, with a lot of variations at the different unit operations. The time allocated, the tools used at different unit operations are adapted to the conditions available at the time. The amount of raw material or input is not well defined for a desired output. Most of the women do not know good hygienic and manufacturing practises. Even those who do know do not respect them a lot.

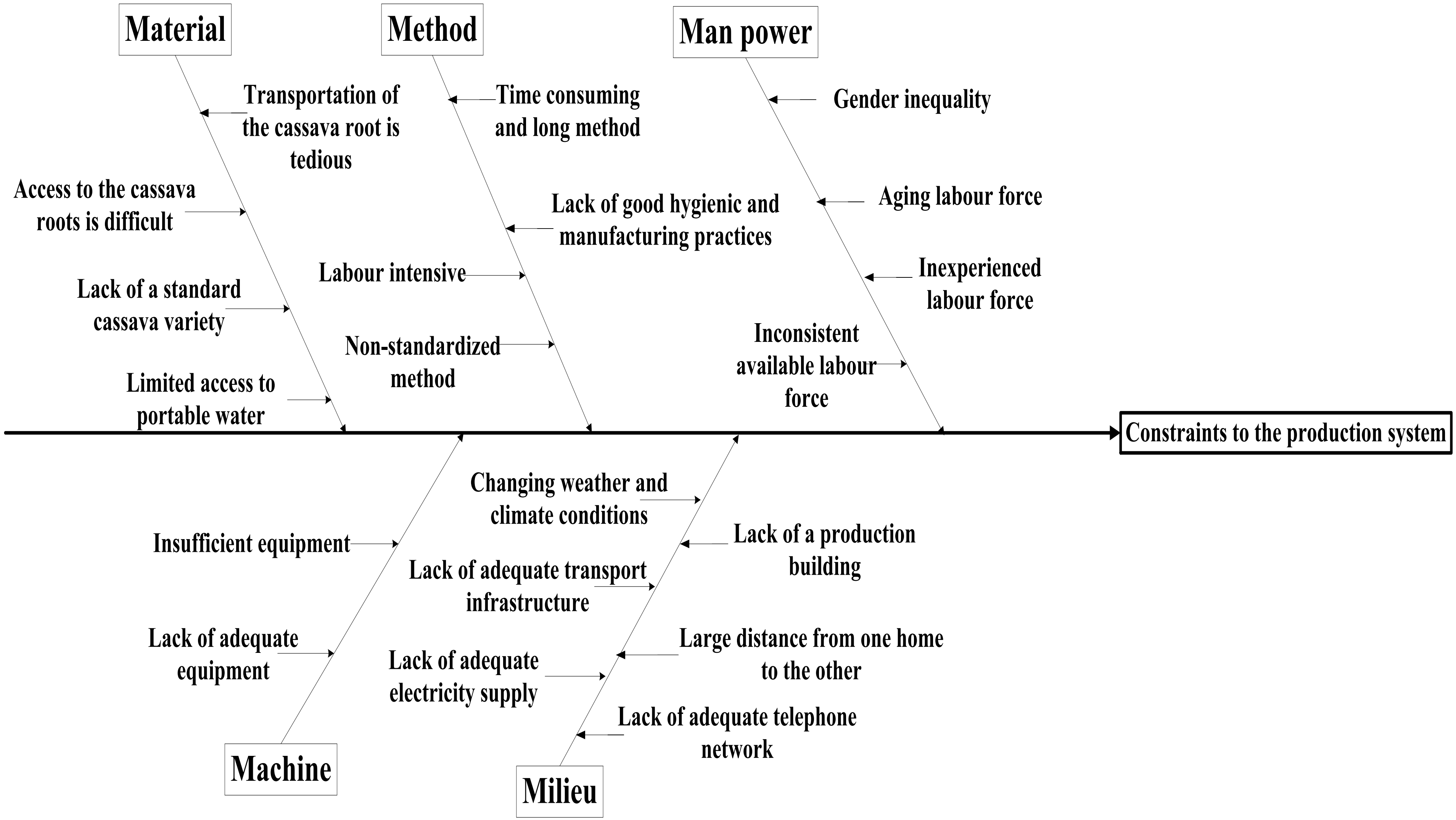


Figure 22: ISHIKAWA diagram of the constraints to the production system in the Nkong Abok locality

✓ **MILIEU**

The women of the platform leave far apart from each other. This causes gatherings to be quite difficult. The Catholic Church is their main point of gathering. This is done on Sunday after Holy mass. This is because it is the only place where the women are theoretical sure to meet one another. Hence, this imparts on the availability of all the actors and explains the fact that it is impossible to gather all the actors for a production.

The weather condition and climate variations in this area, limits the production of cassava starch to be seasonal. There are two main seasons; the main rainy season that starts in mid-August and ends in beginning January, and the dry season that begins in mid-January and ends in mid-July. The rainy season, the problem for the women is during drying, as the method is solar. This limits the production in the rainy season, the women practical do not produce or produce less cassava starch. Also during the rainy season, the women consider that the cassava is not adapted for starch production. They say it does not contain enough water, so during extraction not much of water is pressed out from the rasped cassava. In the dry season, which is the best season for cassava starch production, the problem is mostly at the level of harvesting. Then women find it very difficult to dig out the cassava roots from the soil. Therefore, even though the dry season is the best moment adapted for cassava starch production, it also has its limits.

There is no fixed infrastructure for the production. The principal production site is outdoors in the different house compounds of the various platform members. This limits the production to sunny days.

There is an inadequate supply of electricity. The supply in electricity fluctuates a lot, with many black outs especially during the rainy season. Sometimes the population experience one week of black out, affecting the communication modes. This especially is the case of cell phones that go uncharged for up to a week.

The main means of communication is through mobile or cell phones. With the network being a serious problem in the area, it is not easy to reach to every member, added to the fact that not all the members do possess a cell phone. This contributes to the poor organization of the persons involved in the production system.

Cassava starch is the least produced cassava product mainly because of the existence of a very narrow market. Cassava starch faces a lot of competition with the other cassava derivatives especially batôn de manioc, which is the primary cassava product for the women. Added to that, the women have little knowledge on the market openings of cassava starch. This gives cassava starch a small position in the markets of cassava derived products. Hence, this motivates less the women to increase their production. The distances to the main market are long and the roads leading to them are poor. This renders access to the market difficult especially during the rainy season.

- ✓ **MAN POWER**

The persons involved in the process are mostly, if not all women. They produce the cassava, process it and sell it. For a completely manual process the absence of men at each level of the process makes it more strenuous for the women.

Most of the women are more than 40 years of age, and for a process that is completely manual, it renders the process more difficult for them.

The man power involved in the process is not always available. Due to lack of proper organization and also transportation facilities, the women do not find it easy to meet at the various production sites.

Cassava starch production has just dug its roots in the locality. The women involved in the process are not experts in the domain of production. This is seen by their limited knowledge on Machine

Observation

The process followed up in the locality is described in Figure below. However this process varies according to the conditions at the time as described below:

Peeling

The first operation carried out was peeling. The women used kitchen knives to remove the entire outer skin of the roots. The time taken for this unit operation varied between 3-7 minutes for the different productions.

Washing

The women then washed the peeled cassava roots with in water obtained from the water-spring. This was done by scrubbing the cassava roots with their fingers, to try to remove the dirt on the skin of the roots. The water was carried using plastic buckets, and the roots were washed in 5litres stainless steel basins. This was done by a single woman and the time taken varied between 2-10 minutes. Much time was used when washing was done twice as in the case of mixed starch variety production.

Rasping

The washed were then rasped using a hand rasper. The women grated the washed cassava roots on the surface of the rasper doing an upward and downward of the cassava roots on the surface of the rasper. The number of women involved in this unit operation varied 2 and 4 women. The time taken equally varied from 6-17 minutes, with more time consumed in the case where there were 2 women that did the rasping.

Grinding

The rasped cassava roots were then ground on a grinding stone, using their hands. This was done twice, by 3 women at different intervals. The 2nd grinding was done using a mechanical hand grinding machine. The time taken for this operation ranged between 40 minutes and 1hour 38 minutes. Much more time was taken in the Bitolbikor starch production.

Mixing

The women then took the ground roots and mixed with water in a plastic basin using their hands. This was done by one woman and the time take varied between 2-4 minutes. It took more time in the Ngeunda starch production because the operation was done twice.

Sieving/pressing

For this operation 3 or 4 women were involved. One woman had to transfer the starch suspension from the plastic basin using a small plastic kitchen dish and pour it on a cloth. The cloth was held by two other women, and under it was placed a large stainless steel pot or a plastic bucket, that serve as receptor for the starch slurry or starch milk. The starch suspension on the cloth was swirled by a woman using her hands, allowing the starch suspension should flow across the cloth. When the suspension stopped flowing, two or three women tied the cloth and pressed or squeezed it to let more of the suspension to flow. This took 15-40 minutes and it was done twice for the Ngeunda starch production.

Sedimentation

The starch slurry or milk was then left to sediment in a large plastic bucket or stainless steel pot for a time varying between 1hour 34 minutes and 2 hours 40 minutes. The Ngeunda starch took most of the time, while the Bitolbikor starch took the least.

Drying

The wet starch obtained was dried by 1 or 2 women. The women threw the supernatant water and removed the wet starch with their hands and spread it on a metal sheet place on a table. After some time they removed the starch from the metal sheet and placed on a canvas (plastic) cover, placed on the floor. The drying was done outdoors under the sun. However the drying operation was continued for 2 days because of the poor weather conditions.

Grinding

The dried starch was then ground once more by a woman with the aid of the grinding stone.

Sieving

This last unit operation consisted of sieving of the starch into a powder form. This was done by a single woman.

III.3 Technological evaluation of the starch production system

III.3.1 Process extraction yield

Table 12 presents the yield of the different three productions followed up. The mixed starch variety with 22% presented the highest process yield, while Bitolbikor starch with 10% presented the lowest yield. Overall the cassava starch extraction process of the women of the innovation has a low yield from that described in the literature. According to (Chavalparit *and al*, 2008), 1 ton of fresh cassava root yields 0.24 of native starch (24% process yield). From the results obtained, the fresh roots used are below that expected with an overall yield of 17%. However, Yimmongkol 2009 stated that 4 - 4.4 tons of fresh cassava roots will be needed to yield 1 ton of starch. This gives of yield of between 20-22%. The mixed starch variety gave a yield that fell within this range. This implies that the combination of both cassava varieties may be a solution in obtaining high cassava starch yields.

Table 12: Process yield of the cassava starch extraction process at Nkong Abok

Process	Amount of cassava used in kg	Quantity of starch obtained in kg	Process yield in percentage
Ngeunda starch	5	0.95	19
Bitolbikor starch	5	0.5	10
Mixed starch variety	5	1.1	22
Total yield	**15**	**2.55**	**17**

III.3.2 Water consumed during the cassava starch extraction process at Nkong Abok

Water is the second raw material of the process in the women's extraction process. The water used in the process is presented on table 13. It revealed variations for the three different productions. The mixed starch variety used most of water with 25.3 litres, while the Bitolbikor starch used less water, with 14litres of water used. The results obtained for the mixed starch variety were very close with that described by Marder et al., (1993) who revealed that 21-40 litres of water were used to obtain 1kg of starch in Brazil. This variation in the use of water consumption reveals once more the non-standardize nature of the process.

Table 13: Quantity of water used in the Nkong Abok extraction process

Process	Unit operation	Amount of water used in litres	Unit operation	Amount of water lost in litres
Ngeunda starch	Washing	4	Sedimentation	11.5
	1st Mixing	11.5	Washing	3.7
	2nd Mixing	7.5		
Total amount of water used		**23**		**15.2**
Bitolbikor starch	Washing (twice)	4	Sedimentation	9.65
	Mixing	10	Washing	3.1
Total amount of water used		**14**		**12.75**
Mixed starch variety	Washing	6.3	Sedimentation	18.6
	Mixing	19	Washing	5.8
Total amount of water used		**25.3**		**14.4**
Overall Amount of water used		**62.3**		**42.35**

III.3.3 Material balance at different unit operations

Table 14 presents the material balance done at the level of the different productions. The peeling unit operation revealed that the peeling had a constant percentage loss. However, the rasping unit operation revealed that there was a difference in the percentage loss for the different cassava starch produced. Bitolbikor starch revealed most of the lost, with 2% loss from the peeled roots. During Ngeunda starch production, the lost observed was the least, with a percentage of 0.5% loss. This variation in the percentage loss may be due to difference in the number of persons involved during that unit operation. Other unit operations involved such as grinding also contributed to the losses during processing. Bitolbikor starch production resulted in the greatest loss due to the fact the grinding occurred twice, with 0.75%. This could explain the fact that Bitolbikor starch had the least process yield.

Table 14: Material balance of some unit operations in the process

Unit operation	Mass input(kg)	Mass output(kg)	Percentage loss (%)
Ngeunda starch production			
Unit operation	**Mass input(kg)**	**Mass output(kg)**	**Percentage loss (%)**
Peeling	5	4	20
Rasping	4	3.9	0.5
Grinding	3.9	3.85	0,25
Drying	1.55 (wet starch)	0.95 (dry starch)	38.7 (water)
Bitolbikor starch production			
Unit operation	**Mass input (kg)**	**Mass output (kg)**	**Percentage loss (%)**
Peeling	5	1	20
Rasping	4	3.6	2
1st Grinding	3.6	3.5	0,5
2nd grinding	3.5	3.45	0,25
Drying	1.45 of wet starch	0.5 of dry starch	65.5 (water)
Mixed starch variety production			
Unit operation	**Mass input (kg)**	**Mass output (kg)**	**Percentage loss (%)**
Peeling	5	4	20
Rasping	4	3.75	1.25
Grinding	3.75	3.6	0.25
Drying	**1.85 (wet starch)**	**1.1 (dry starch)**	**40.5 (water)**

III.4 Physico-chemical analysis

III.4.1 Water, starch, ash and cyanide content of the dry cassava roots

Table 15 presents; the water content, total starch content, ash content and the cyanide content of the two cassava varieties. The water content values; 12.93% and 13.2% for Ngeunda and Bitolbikor respectively, did not present any significant difference. The amount of dry matter is used to determine the water content obtained. The dry matter content obtained was, 87.07% and

86.8% for the Ngeunda and Bitolbikor samples respectively. The amount of dry matter reflects the starch content in the samples.

There was no significance difference in the total starch content between both samples. The values obtained for Ngeunda and Bitolbikor (75.96% and 71.26% respectively) fell out of the range for the starch content of cassava roots proposed by Breuninger et *al*., 2009 (77-94% w/w dry basis).

There was a significant difference between the ash content and cyanide content of both samples. Ngeunda with 1.83% and 18.49%, presented a lower ash and cyanide content respectively. On the other hand, Bitolbikor presented a higher ash and cyanide content of 2.53% and 25.18% respectively. The cyanide content gives information on type of cassava variety. The values obtained for Ngeunda and Bitolbikor (18.49 and 25.18 respectively) fell below 100mg. According to Hongbete, 2004; these cassava varieties are sweet cassava varieties. These values fell below 50mg HCN/kg implying that it is innocuous as described by Coursey (No date).

Table 15: Water, starch, ash and cyanide content of the dry cassava roots

Water content (Percentage)	**Starch (Percentage)**	**Ash (Percentage)**	**Cyanide (mg HCN/kg dry matter)**
12,93±0,23[a]	75,96±0,98[a]	1,83± 0,01[a]	18,49± 0,22[a]
13,2 ±0,69[a]	71,26± 3,68[a]	2,53± 0,35[b]	25,18±0,94[b]

The letters in the table in the same column, with the same letters, present no significant difference at 95% confidence interval.

III.4.2 Physico-chemical composition of the cassava starch samples

Table 16 presents the physico-chemical composition of the cassava starch samples. There exist a significance difference between the water content of the Ngeunda variety and the mixed variety. The mixed starch variety had the greatest water content 17.96%, while the Bitolbikor starch had the least water content 16.4%. The Ngeunda starch showed no significance difference between the other two samples. All the values of the water content were above that recommended for food grade starch (12%) as given by CD-ARS, 2012. The dry matter obtained revealed Bitolbikor as the starch sample with the highest dry matter (83.6%). The mixed starch variety had the least dry matter content (82.04%). Bitolbikor starch lost the greatest amount of water (65.5% water loss) during the drying unit operation. But the water content of the Ngeunda and the Bitolbikor starch revealed no significant difference. Therefore, it could be deduced that the Bitolbikor cassava variety contained a higher amount of water than the Ngeunda starch.

Table 16: Physico-chemical composition of the cassava starch samples

	Water content (%)	Starch content (%)	Amylose content (%)	Amylose: Amylopectin ratio	Ash content (%)	Cyanide content (mg HCN/kg dry matter)	pH	Total acidity (mmol/100g of dry matter)	Water absorption capacity (g water/g starch)	Solubility index (%)
Ngeunda starch	17,33±0,61[ab]	95,22±1,53[a]	22,97±3,3[a]	0,29±0,05[a]	0,481±0,001[a]	14,08±0,31[a]	4,6±0,0[a]	0,20±0,00[a]	104,52±2,60[a]	23,5± 2,82[a]
Bitolbikor starch	16,4±0,56[a]	85,14±0,23[b]	22,51±0,30[a]	0,29±0,005[a]	0,50±0,04[a]	9,42±0,78[b]	4,82±0,11[b]	0,19±0,00[a]	123,43±4,12[b]	20,25±2,47[a]
Mixed starch variety	17,96±0,51[b]	92,59±1,14[a]	21,65±2,22[a]	0,26±0,01[a]	0,487±0,003[a]	5,36±0,83[c]	5,06±0,11c	0,20±0,00[a]	103,16±1,70[a]	20,25±0,35[a]

The letters in the same column in the table, with the same letters present no significant difference at 95% confidence interval.

This is because it took a longer time to reduce a higher amount of water content from the Bitolbikor starch compared to the Ngeunda starch. This high water content could be explained by the influence of the season. The cassava variety was collected during the beginning of the first rains, announcing the rainy season. However, this implies that the drying conditions in the Nkong Abok locality are not of adequate.

The total starch content of the samples varied from 85.14%-95.22%. The starch content of the three samples showed there was a significance difference between Bitolbikor starch and the other starch samples. The starch content of Ngeunda starch and the mixed starch variety (95.22% and 92.59% respectively) showed no significance difference. The Ngeunda starch had the greatest starch content (95.22%) while the Bitolbikor starch showed the least starch content (85.14%). The mixed starch with best yield during the production had one of the best starch qualities, while the Bitolbikor starch with the poorest yield equally had the least the starch quality. This reveals that the Ngeunda variety produced starch of better content, compared to the starch from Bitolbikor variety. The mixture of both varieties gave a better starch content than that of Bitolbikor variety. This could be linked to the higher water content of the Bitolbikor cassava variety. However, only Ngeunda starch had a total starch content that respects the ARS (2012) requirements (95%).

The amylose content of the three different samples showed no significant difference in their means. Ngeunda starch had the highest mean value 22.97%, followed by Bitolbikor starch with 22.51% and lastly the mixed starch variety with 21.65%. These values are higher than that (18.8±3.6%) found by Mweta, (2009). However, the values fall in the range for the cassava varieties (13.6-23.8%) as displayed by (Moorthy, 2002; Tian and al., 1991). The amylose: amylopectin ratio was the same for all three samples. Ngeunda and Bitolbikor had the same value 0.29, while the mixed variety had 0.26. The ratio for the amylose: amylopectin were greater than 0.25. Leach and al. (1969) revealed that starches with amylose: amylopectin higher than 0.25 are more susceptible to retrogradation. This means all are starch samples will not be adapted in sectors where synaeresis has high negative effects such as in formulation of infant food or in cooking waterfufu.

The ash content of the three samples was the same, with no significant difference in their means. Usually the ash of commercial starches contains mainly sodium, potassium, magnesium, and calcium as metal compounds (Perez, 2000). This therefore gives information on the purity of the cassava starch. Hence, in terms of purity our starch samples were mainly consisted of starch with no impurities.

There exists a significant difference between the cyanide content of all three starch samples. Ngeunda starch had the highest cyanide content (14.08), and this is more than the cyanide content accepted for food grade starch. The cyanide content of Bitolbikor starch (9.42mg/kg) and the mixed starch variety (5,36mg/kg) falls within accepted values for food grade starch according to ARS, (2012). Ngeunda starch had a higher content (14.08mg/kg) implying it should not be used in food applications.

The pH values of the three different samples were all significantly different. The mixed starch variety had the greatest pH value (5.06) while Ngeunda starch had the lowest pH value. The values of the total acidity did not reveal a significant difference between the samples.

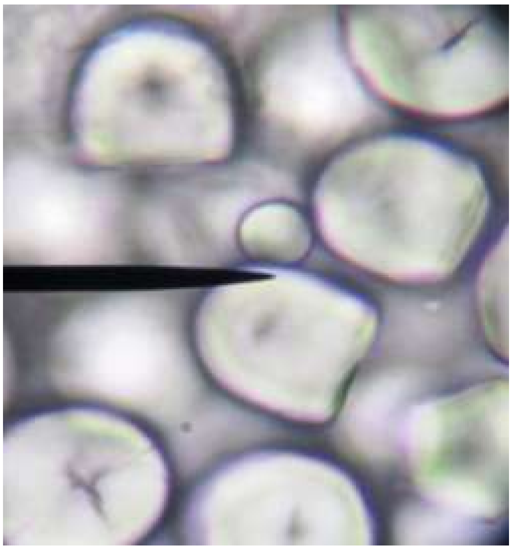
The water absorption capacity of the Ngeunda starch and the mixed starch variety showed no significant difference between them. Bitolbikor starch had a water absorption capacity significantly different from the other starch samples. With 123g of water absorbed/100g of dry matter, Bitolbikor starch had the highest WAC value. Mixed starch variety had the lowest water absorption capacity. The water absorption capacity is related to the solubility index. The solubility index varied from 20.25%-23.5%. The three starch samples presented no significant difference between them. The Ngeunda starch had the greatest solubility (23.5%), while the mixed starch variety had the lowest value.

III.4.2 Degree of Gelatinization

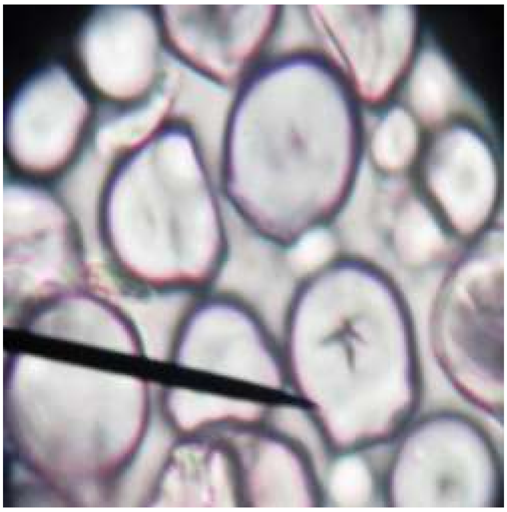
The results obtained from the gelatinization degree are presented in table 17 below. The degree of gelatinization for the different starch samples increased from 50°C up to 90°C. While the degree of gelatinization for Bitolbikor starch dropped at 100°C, that of the other two samples continued till 100°C. This implies that Bitolbikor starch gelatinizes faster than the other starch samples. Ngeunda starch continued to gelatinize up to 100°C, while the mixed starch variety seemed to reach a stable gelatinization degree. Picture 3 and 4 below, represent the granule shape of the Ngeunda and Bitolbikor starch. From the microscopy we could deduce that the Bitolbikor starch had granular sizes smaller than that of the Ngeunda start. This is a factor that influences the gelatinization degree of the starch samples and it could it explain the slight differences in the higher gelatinization of Bitolbikor starch compared to Ngeunda starch.

Table 17: Percentage gelatinization in relation to temperature

Temperature in °C	Percentage gelatinization (%)		
	Ngeunda starch	Bitolbikor starch	Mixed starch variety
50	13,94956332	16,73390982	21,44998423
60	61,68415525	60,43269153	60,73647328
70	72,26786448	67,12810238	67,32886293
80	84,54294997	80,79954018	85,15978832
90	92,62483136	93,14364756	95,25126448
100	98,08785184	91,86700998	96,25197669



Picture 3: Ngeunda starch granule size



Picture 4 Bitolbikor starch granule size

III.4.3 Pasting properties

Table 18 presents the pasting properties of the three starch samples. The parameters observed are; pasting temperature, peak viscosity, hold viscosity, final viscosity, breakdown viscosity, setback viscosity. The pasting temperature of the three samples showed no significance difference between them. The mixed starch variety had the highest mean 66.68°C, followed by Ngeunda starch with 66.25°C and finally Bitolbikor starch with 65.9°C. The values obtained are closed with that found by Dufour and al. (1995). Dufour found a pasting temperature of 62.5°C in sour starch from cassava varieties of CMC 40, Amarga and Algodona. Liu, (2005) showed that cassava starch together with potato starch have the lowest pasting temperature (69.5 and 65.6°C respectively). The values obtained matched with that of Liu, (2005). The pasting temperature provides an indication of the minimum temperature required to cook a given sample. This therefore implies that our starch samples could be used in applications where less energy is required to cook the starch granules, as is the case of brewing industry.

The values of the peak viscosity observed revealed a significant difference in the three different samples. Ngeunda starch presented the highest peak value with 4744mPa.S, followed by Bitolbikor starch with 4233mPa.S and finally mixed starch variety had the lowest value of 3944mPa.S. All three starch samples revealed a higher peak viscosity than that found by Liu, (2005) (2249mPa.S). Wickramasinghe and *al*. (2009) reported a positive relationship of peak viscosity and median particle size of the starch granule. Implying that, starches with large granules displayed a higher paste peak viscosity. Therefore this confirms our deduction that Ngeunda starch had larger granules than Bitolbikor starch. Peak viscosity occurs at the equilibrium point between swelling and polymer leaching. It gives an idea on the ease at which the starch sample could be cooked, as it gives an indication of the viscous load likely to be encountered by a mixing cooker. A higher peak viscosity corresponds to a higher thickening power (Khatijah and *al*, 1998), this could then imply that the Ngeunda starch may be well adapted in applications where high thickening characters are desired.

The breakdown viscosity of Ngeunda starch was significantly different to those of Bitolbikor and the mixed starch. While Bitolbikor and the mixed starch showed no significant difference. The breakdown viscosity is the difference between peak viscosity and the hold viscosity. It reveals the stability of the starch gels during processing conditions. Ngeunda starch with the highest breakdown of 3026°CmPa.S reveals that it had the least stability to shear stress. This implies that Ngeunda could not be used for technological purposes, where a good texture and cohesive forces of starch sample are desired (Crosbie and Ross, 2009). This implies that, mixed starch variety with the lowest breakdown viscosity 2459mPa.S, will better adapted in formulation of thickeners used in food industries.

The final viscosity of the starch samples revealed a significant difference between all the starch samples. Ngeunda with the highest (2964mPa.S) followed by Bitolbikor 2501°C and finally the mixed starch variety 2244°C. The values obtained are higher than that found by Liu, (2005) (1437mPa.S). The final viscosity gives an indication of the stability of the cooled, cooked paste under low shear. Starch samples with higher final viscosity will have a higher tendency to suffer retrogradation (Moorthy, 2002). Hence this implies that our starch samples will have a high tendency to exhibit synaeresis as consequence of retrogradation.

The setback observed for the starch samples are not all significantly different. Ngeunda starch showed the highest set back value 1246mPa.S which was different from that of the mixed starch variety, with the lowest setback value of 759mPa.S. The setback value displays the ability for the starch samples to resist to retrogradation. The values obtain are close to that revealed by Liu, (2005) for cereals starch (Wheat 1308mPa.S, Normal maize 1302mPa.S). This reveals that the starch samples have a high tendency to synaeresis. This matches with the values of amylose obtained. As a high amylose content reflects higher tendency for retrogradation.

Table 18: Pasting properties of the Cassava starch samples

Samples	Parameters	Pasting Point	Peak Viscosity	Hold Viscosity	Final Viscosity	Breakdown	Setback
Ngeunda starch	Viscosity(mPa.S)	14,0±1,41[a]	4744,5±92,63[a]	1718,0±74,95[a]	2964,0±0[a]	3026,5± 17,67[a]	1246,0±74,95[a]
	Temperature(°C)	66.25	80.66	91.59			
Bitolbikor starch	Viscosity(mPa.S)	18,0±2,82[a]	4233,0±21,21[b]	1650,0±7,07[a]	2501,0±0[b]	2583,0±14,14[b]	851,0± 7,07[b]
	Temperature(°C)	65.9	79.79	92			
Mixed starch variety	Viscosity(mPa.S)	18,5±2,1[a]	3944,0±97,58[c]	1484,5±24,74[b]	2244,0±0,0[c]	2459,5±122,32[b]	759,5±24,74[b]
	Temperature(°C)	66.68	80.94	92.98			

The letters in the same column in the table, with the same letters present no significant difference at 95% confidence interval.

III.5 Financial evaluation of the Nkong Abok cassava starch process

After analysing the process and the quality of the starch produced, the financial evaluation was carried to determine whether the women do gain some money from their activity. The financial evaluation done here is to determine gross profit of the production system. A negative gross profit will indicate the non-profitable nature of the process, while a positive gross profit will indicate a profitable nature.

- ✓ **Calculation of the working Capital**

Working capital: This is the money that is used to maintain inventory and cover operational costs. In this case it consists of the cost of the raw material and the labour cost.

Table 19: Cost of raw material of the Nkong Abok production system

Raw Material	Quantity	Unit Price/kg	Cost/day	Cost/year
Cassava roots	50	100Fcfa	5000Fcfa	1800000Fcfa
Total	50		5000Fcfa	1800000Fcfa

- ✓ **Labour cost:** This refers to the amount of money granted to the cassava producers as salary/day.

Table 20: Labour cost of the Nkong Abok production system

Designation	Quantity	Number of working hours	Salary per Hour in (Fcfa)	Salary/day	Salary/year
Workers	1	9	100	900Fcfa	3240000Fcfa
Total	14	9	100	14000Fcfa	5040000Fcfa

- ✓ **Depreciation cost:** Equipment gradually wears out when it is used, and depreciation is a method to accumulate sufficient funds to buy a replacement at the end of its working life. The method used here was that of the linear or straight line method. It consisted of dividing the cost of the equipment by the number of expected working years of the equipment.

Table 21: Depreciation cost of the equipment used in the Nkong Abok

Tools	Quantity	Unit price/kg (Fcfa)	Monthly cost	Working life expectancy (in years)	Depreciation cost/year (Fcfa)
Kitchen	2	950	1900	5	380
Plastic bucket	1	2000	1500	5	300
Hand raspers	2	3000	6000	3	2000
Grinding stone	1	2500	2500	10	250
Mechanical hand-machine	1	17500	17500	10	1750
Plastic basin	2	2500	5000	5	1000
Piece cloth	1	2000	2000	3	667
Stainless steel large pot	1	45000	45000	10	4500
Sheet-metal	1	4500	4500	10	450
Kitchen sieve	1	750	750	5	150
Bundle of canvas cover in meters	1	15000	15000	5	3000
Total			**101650Fcfa**		**14447Fcfa**

- ✓ **Production cost**

This consisted of summing the variable and fixed cost.

Table 22: Production cost of Nkong Abok production system

	Different cost	Value per year
Variable cost	Cost of raw material Labour cost	1800000Fcfa 5040000Fcfa
Fixed cost	Depreciation cost	14447Fcfa
Total cost		**6854447Fcfa**

- **Sales income**

From the survey, the women revealed that for 50 kg of cassava processed, between 8-10litres of starch is obtained. Therefore, an average amount of 9litres of cassava starch was considered to be produced monthly.

The formula for the sales income is given by:

Sales income = Quantity sold X unit price

Table 23: Sales income of the Nkong Abok production system

Final product	Quantity	Unit Price/kg	Price/day	Price/year
Cassava starch	9	1000Fcfa	9000Fcfa	3240000Fcfa
Total	9		9000Fcfa	3240000Fcfa

Gross profit = Income from sale – expenditure before tax

Expenditure (Variable cost + Fixed cost) = 6854447Fcfa

Income = 3240000 Fcfa
Gross profit = 3240000-6854447

Gross profit = -3614447Fcfa

From all these results obtained it is therefore possible to say that the cassava starch extraction process in the central region of the country is an activity that does permit the financial progress of the population. It is from these results that a profitable improved process was proposed, to serve as solution to contribute to the financial development of the population.

III.6 Proposal of an improved process

After studying the existing state of local cassava starch production, the following proposals for an improved production system were brought to complete this work. This was done using the PIDMA document, 'Etudes complémentaires sur les semences, la mécanisation Agricole et la transformation du maïs et du manioc dans le cadre de la conception et de l'appui à la pré-évaluation du projet'. The PIDMA project wishes to contribute to the development of rural producers. But one of the conditions for this to occur is that the people should be organized into associations, CIG or cooperatives. This explains the reason for the choice of our locality to be at the Nkong Abok innovation platform.

III.6.1 Elaboration of the proposed production unit

III.6.1.1 Location of the production unit

The production unit will be situated close to the catholic church of the Nmom Nam village. The site of the location was chosen with respect to the facility of gathering all the actors of the innovation platform. A floor plan of the proposed production building is illustrated in figure 23 below

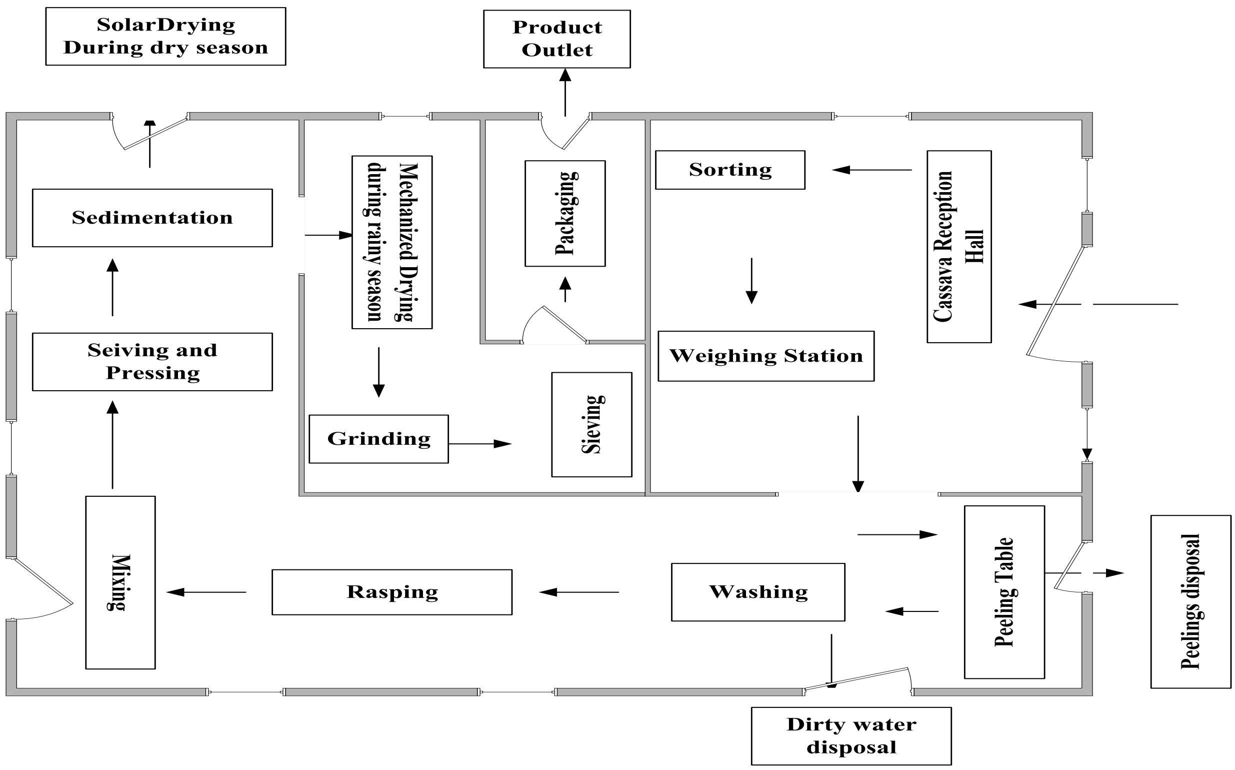


Figure 23 : Floor plan of the production unit

III.6.1.2 Choice of raw material

Due to the variation in the starch content from one cassava variety to the other, the choice of the cassava root used in the process is a determining factor. According to Vessia (2007), bitter cassava varieties have higher starch contents than sweet varieties. Hence the cassava root chosen here will be that of 8034. The reason for this choice is first because the variety is already grown in some of the farms at the level of the innovation platform. Hence there is already a potential raw material source available.

Water is the second raw material that is very important for the completion of the process. The water used will come from a water spring already present in the Nmom Nam village. There presently exist two water springs at the catholic church of the Nmom Nam village.

II.6.1.3 Choice of the unit operations

The unit operations involved will be maintained as before, with some precision or modifications on how the operation should be carried out. The only new operations that will be introduced are that of weighing and sorting. The unit operations are described in the block diagram below:

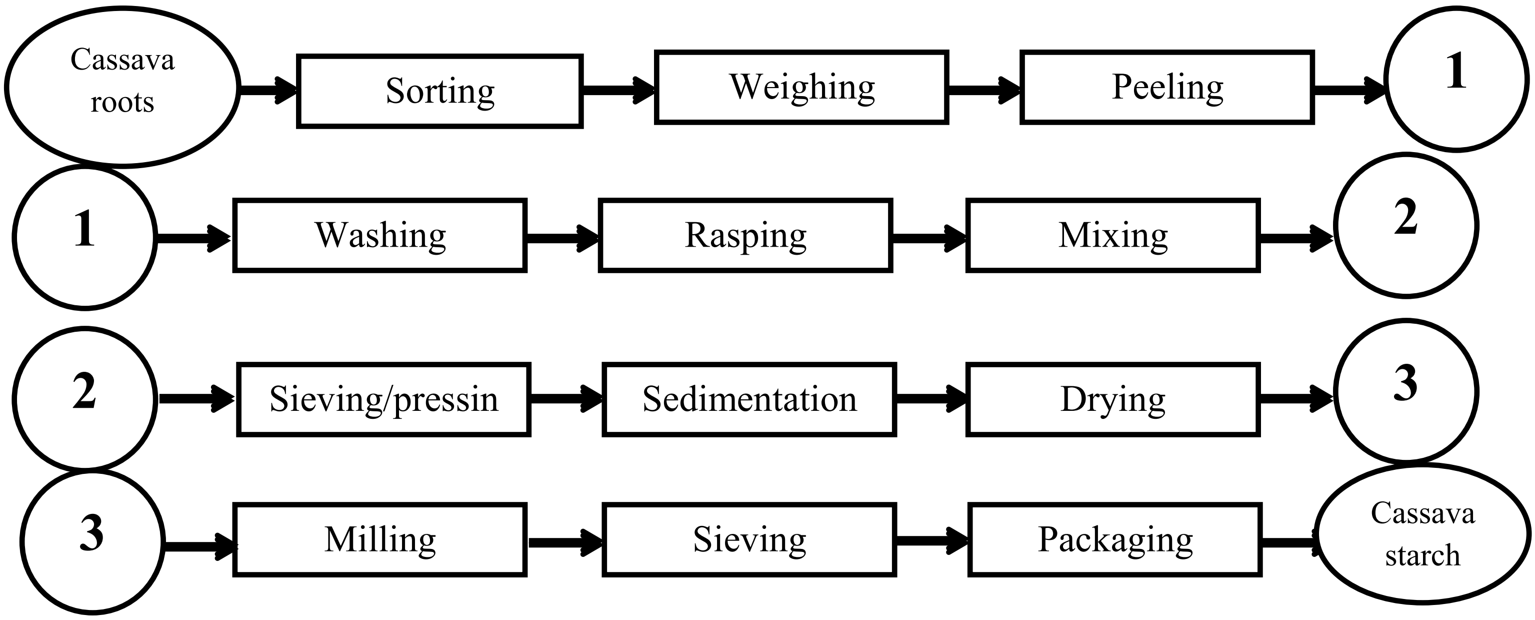


Figure 24 : Block diagram for the proposed cassava extraction process

III.6.1.4 Description of the operations of the proposed process

The unit operations should be carried out as follows:

Table 24: Description of the operations of the proposed process

Operation	Summary description	Equipment or material used
Sorting/Weighing	The cassava roots should be selected on arrival at the production unit. Rotten and injured roots should be rejected and discarded. The selected roots should then be weighed to the desired quantity.	Weighing machine capacity:0-300kg, Woven Baskets
Peeling	As done in their actual process. The peeled roots should be immersed into clean water contained in a stainless steel basin to avoid for oxidation to take place.	Stainless steel knife, stainless steel basins
Washing	The peeled cassava roots will be used with water obtained from the water-spring. The cassava roots will be scrubbed with a clean sponge, until a complete white colour is observed.	Kitchen sponge, stainless steel basin
Rasping	Done using a clean stainless steel kitchen bowl. The clean peeled cassava roots are introduced into the gravity grater and then collected using a clean stainless steel bowl. The cassava shall be pushed against the grating surface using a stainless steel kitchen spatula	Gravity cassava grater: Yield: 1t/h diesel engine or electrical; 7CV 7000rpm. Manual starting.
Mixing	Done as before.	Stainless steel basin

Table 25: Continuation of the ddescription of the operations of the proposed process

Operation	Summary description	Equipment or material used
Sieving/pressing	The cassava starch suspension shall be poured on the sieves and it shall be collected in clean woven polyethylene plastics. The woven plastics shall be placed on the hydraulic press and the starch solution collected using a stainless steel basin.	Jack press: Capacity: Up to 100 Kg of wet product per batch (10-15 min batch)
Sedimentation	As done before	Using sedimentation tanks, in the form of drums capacity 500-1000litres
Drying	The wet starch should be collected using properly washed hands. Then, placed in a stainless steel basin and then dried depending on the season. During the dry season: dried outside on table racks covered with a canvas polyethylene plastic. During the rainy season: dry using mechanical dryer.	Table rack of 20 meters long, Dryer capacity: Capacity: 100kg; source of energy: wood.
Milling	With properly washed dried hands, the dried starch should be collected in a stainless steel basin and then milled in the miller	Cassava miller: Yield: 400kg/h; diesel engine or electrical.
Sieving	As done before. Using kitchen sieves, the milled starch should be sieved using clean dried hands into a stainless steel basin	Kitchen sieve
Conditioning	Into woven sac the final starch will be introduced and sealed at the top	Woven sac with polyethylene lining

III.6.2 Financial evaluation of the proposed production system

The financial evaluation consisted of comparing the capital invested in the proposed process and the entire expenses of the proposed process. In order to realise this there was the need to set the assumptions considered for the analysis. Having determined the invested capital, the profitability of the process was determined. To realise this, three criteria were used; Net present value (NPV), profitability index PI (IP) and the break-even point (BEP)

The financial analysis was carried out based on the following assumptions;

- ✓ The women of the Nkong Abok innovation platform will have to contribute 10% of the investment cost, PIDMA will contribute 40% of the investment cost, and 50% will be taken as loan from the bank.
- ✓ The women will be able to produce 1ton of cassava starch per day and sell to an existing market.
- ✓ The interest rate, (i) will be 15%
- ✓ The growth rate of the production capacity will be assumed to be 5% each year.

III.6.2.1 Investment cost

The investment for the proposed production unit will be done on the following materials

- ✓ Gravity cassava grater
- ✓ Sedimentation tanks
- ✓ Mechanical dryer
- ✓ Mechanical Jack press
- ✓ Cassava flour miller
- ✓ Vehicle
- ✓ Weighing Balance

A cost for the installation of the following materials will also be allocated, and the cost for the formation of the workers will equally be introduced. The working capital was also included in this calculation as it reveals the finances necessary for the production system during the early periods of the business or project.

III.6.2.2 Production cost

This is based on a production capacity of the 5tons of cassava roots transformed every day. The working hours per day shall be 8 hours. The working days per month shall be 26 days and the number of months considered shall be 12 months. The cost of production will include the cost of the fixed assets, the labour cost, the direct charges and indirect charges and the depreciation cost.

Table 26: Investment cost of the proposed process

Equipment	Quantity	Unit cost(Fcfa)	Total Price(Fcfa)
Gravity cassava grater	1	2500000	2500000
Sedimentation tanks	4	50000	200000
Dryer	1	5500000	5500000
Jack press	1	1200000	1200000
Cassava flour miller	1	1200000	1200000
Toyota, thundra pick-up vehicle	1	11000000	11000000
Setting up of equipment		500000	500000
Formation		100000	100000
Weighing Balance	4	500000	2000000
Working capital			87029300
Construction	300m^2	2000	600 000
Total			**111 829 300**

- ✓ **Fixed assets**

This comprises the cost of those equipment owned by the women and that do not change with increase in the production size.

Table 27: Fixed assets cost of the processed process

Designation	Quantity	Unit price	Total price	Expected working life (in years)	Depreciation cost/year
Kitchen knife	10	800FCFA	8000FCFA	5	1600FCFA
Bundle of canvas cover, in meters	20	15000FCFA	300000FCFA	5	60,000FCFA
Plastic buckets, capacity 20litres	10	4000FCFA	40000FCFA	5	8000FCFA
Total					**69,600FCFA**

✓ **Labour cost**

The personnel for the production system will consist of an agro-process engineer, a maintenance engineer and finally unskilled labourers.

Agro-process engineer: The role of the agro-process engineer will be to grantee for the overall good nature of the process.

Maintenance technician: The function of the technician will be to ensure that all the mechanized equipment functions as planned. Also he/she will equally prevent for the occurrence of the malfunctioning of the equipment and take of any repairs.

Financial secretary: He or she will be in charge of the finances of the production unit.

Table 28: Labour cost of the proposed process

Personnel	Number	Unit cost Fcfa/hour/head	Working hours/day	Total cost/day	Total cost in a month(Fcfa)	Total cost/year(Fcfa)
Agro-process engineer	1	1500	8	12000	312000	3744000
Maintenance technician	1	1500	8	12000	312000	3744000
Financial secretary	1	1500	8	12000	312000	3744000
Labourer	15	200	8	24000	624000	7488000
Driver	1	200	8	1600	41600	499200
Total				**61600**	**1601600**	**19219200**

- ✓ **Depreciation cost**

Table 29: Depreciation cost of the proposed process

Designation	Characteristics	Unit price(Fcfa)	Expected working life in years	Depreciation cost/year(Fcfa)
Gravity cassava grater	Yield: 1t/h diesel engine or electrical; 7CV 7000rpm. Manual starting.	2 500 000	10	250 000
Dryer	Capacity: 100kg; source of energy: wood.	5 500 000	10	550 000
Cassava flour miller	Yield: 400kg/h; diesel engine or electrical.	1 200 000	10	120 000
Tools		348 000	5	69 600
Weighing Balance	Capacity:0-300kg	500 000	10	50 000
Jack press: Capacity: Up to 100 Kg of wet product per batch (10-15 min/batch)	Capacity 600kg of mash (2 – 3h pressing)	1 200 000	10	120 000
Toyota, thundra	5 doors, 5 passengers, distance travelled:98274Km/h	11 000 000	5	2 200 000
Sedimentation tanks	500-1000litres	50 000	10	5 000
Building	Capacity: 300m2	600 000	20	30 000
Total		**12 700 000**	**10**	**3 394 600**

Table 30: Total production cost of the proposed process

Designation	Unit	unit price(Fcfa)/day	Quantity	Total cost/day(Fcfa)
		Direct charges		
Raw material	Kg	75	5 000	375 000
Package	50kg	1 000	20	20 000
Total 1				**395 000**
		Indirect charges		
Labour			61 600	61 600
Depreciation			3 394 600	10 880.13
Fuel (gas)	Litre	520	40	20 800
Total 2				162 880.13
Grand total				557 880.13
Total Production cost	**Kg**	**557.88**	**1000**	**557 880**

- ✓ **The interest rate**

The bank loan that will be taken will be reimbursed using constant annuity. An annuity is defined as a series of payments (or receipts) of a fixed amount for a specified number of periods. Each payment is assumed to occur at the end of the period.

The annuity is obtained by the following formula:

Annuity is sum of the amortization plus the interest value. That is,

Annuity= Amortization + interest value

The interest value is obtained as follows:

Interest = Capital*interest rate

The capital as from the second year is obtained as follows

Capital of the next year = capital of the previous year- amortization of the same previous year

The capital borrowed comes from 50% of the total investment cost. This gives an amount of 55914650 Fcfa.

Table 31: Calculation of the amount of money to be paid after taking a bank loan

Capital(Fcfa)	Interest(Fcfa)	Amortization(Fcfa)	Annuity(Fcfa)
55 914 650	8387197.5	8293012.205	16680209.71
47621637.79	7143245.669	9536964.036	16680209.71
38084673.76	5712701.064	10967508.64	16680209.71
27117165.12	4067574.767	12612634.94	16680209.71
14504530.18	2175679.527	14504530.18	16680209.71
	27486398.53	**55914650**	**83401048.53**

✓ **Sales income**

The sales considered here will be for two products; the cassava starch and the cassava peelings. The sales figure is calculated as follows

Sales figure = Quantity X Unit price

Table 32: Sales income for the proposed project

Designation	Quantity (Kg)	Unit Price (Fcfa)	Amount (Fcfa)
Sales income (starch)	312 000	750	234 000 000
Sales income (peelings)	312 000	20	6 240 000

III.6.2.3 Financial statement

This consists of a table that contains all the information of the financial parameters of the proposed process. This table contains the cash flows, the Net present value NPV (VAN), profitability index PI (IP) and the break-even point (BEP) or the pay-back period.

Table 33: Financial statement of the proposed process (in franc CFA)

Year			1	2	3	4	5
Investment		111 829 300					
Quantity sold (growth rate =0,05)	1,05		624 000	655 200	687 960	722 358	758 475,90
Sales figure (selling price=)	770		480 480 000,00	504 504 000,00	529 729 200	556 215 660	584 026 443
Total charges (Normal cost=)	557,88		348 117 200,00	365 523 060,00	383 799 213,00	402 989 173,65	423 138 632,33
Bank loan							55 914 650
Interest on bank loan (0,15%)			8 387 197,50	7 143 245,67	5 712 701,06	4 067 574,77	2 175 679,53
Depreciation			3 394 600	3 394 600	3 394 600	3 394 600	3 394 600
Non-imposed profit			120 581 002,50	128 443 094,33	136 822 685,94	145 764 311,58	99 402 881,14
Imposition (Taux=38.5%)			46 423 685,96	49 450 591,32	52 676 734,09	56 119 259,96	38 270 109,24
Net Profit			74 157 316,54	78 992 503,01	84 145 951,85	89 645 051,62	61 132 771,90
Depreciation			3 394 600	3 394 600	3 394 600	3 394 600	3 394 600
CF			77 551 916,54	82 387 103,01	87 540 551,85	93 039 651,62	64 527 371,90
(1+i)-n			0,87	0,76	0,66	0,57	0,50
Actual CF			67 436 449,16	62 296 486,21	57 559 333,84	53 195 722,78	32 081 508,10
Cumulated CF			67 436 449,16	129 732 935,37	187 292 269,21	240 487 992	272 569 500,10
NPV			(44 392 850,84)	17 903 635,37	75 462 969,21	128 658 692	**160 740 200,10**
PI			0,60	1,16	1,67	2,15	**2,43**
Payback Period	Between the 1st and 2nd year						

The following terms and formulas helped us to elaborate the financial statement above

Actualization rate = $(1+i)^{-n}$

Numbers of years = n

CF=cash flow: The cash flow is a 12-month projection that forecast the receipts (or income) and disbursements (or expenses) of a business or project. The cash flow financial statement shows the inflows and outflows of a financial activity for a specified period.

Non-imposable profit: This is the gross profit without taxation.

Net profit value (NPV): is the excess of the present value (PV) of cash inflows generated by the project over the amount of the initial investment (I). In this case PV is the cumulated cash flow.

Profitability index (PI): The profitability index, also called present value index is the ratio of the total PV of future cash inflows to the initial investment, that is, PV/I. It measures the relative advantage that the project can offer. In simple terms it expresses the revenue generated by 1franc of the capital. For the project to be acceptable, this index should be greater than 1.

Formulas

Non-imposable profit = Gross profit – total charges

Imposable profit = non-imposable profit – Depreciation

Imposition = 0.385*Imposable profit

Net profit = imposable profit – imposition

Cash flow = Net profit + Depreciation

Actual cash flow = $CF*(1+i)^{-n}$

NPV = $*(1+i)^{-n} - I$

Where I: Investment cost

Profitability index

PI = $*(1+i)^{-n}) /I$

Break-even point

Break-even point or payback period is a period at end of which the cumulated CF builds up to the invested capital. Using two periods with their known cumulated CF; one below and the other above the invested capital we extrapolate the BEP. This is determined as;

Where;

n_1 is the duration for the project to cumulate actualise CF close to but less than the invested capital.

n_2 is the duration for the project to cumulate actualise CF close to but greater than the invested capital.

cCFn is the cumulated CF at time n given by;

$$cCFn = \sum CF*(1+i)^{-n}$$

cCFn1 is the cumulated actualised CF for the period n_1.

cCFn2 is the cumulated actualised CF for the period n_2.

There BEP point will be

BEP= 1 + ((111 829 300-67 436 449.16) / (129 732 935.37-67 436 449.16))* (2-1)

BEP = 1.7 years. Hence the payback period is between the 1st and the 2nd year.

From the financial evaluation of the proposed process, we could realise that the money invested will be completely gained in the second year with a cumulated cash flow of 129 732 935 Fcfa, a NPV of 17 903 635 Fcfa and a profitability index of 1.16. At the end of the fifth year the loan would be completely paid, and the cumulated cash flow will be 272 569 500 Fcfa, with a profitability index of 2.43. This implies that considering the main product (cassava starch) and the valorisation of the by-product (cassava peelings), cassava starch processing could be very profitable and could be a source of development for the rural population.

RECOMMENDATION

In order for cassava starch to become part of the main derivative products in the Cameroonian market, the following points should be done;

- The women should practice extensive cultivation of the 8034 cassava variety and other improved cassava varieties.
- The men in the innovation platform should contribute more to the cassava starch production system, especially in terms of man power.
- Cassava producers should get more involved in starch production, and try to assess the existing market

CONCLUSION AND PERSPECTIVES

Cassava starch production in the central region of Cameroon is not a lucrative activity. The activity is carried out more as a secondary activity to compensate for other personal charges. The actors of the value chain are isolated, with a poor collaboration between them. The traditional method of the process limits the scale of the production. The cassava starch production system is characterized by some many constraints, particularly in terms of the equipment used and the method adopted. This leads to the incapability of the local cassava starch to respond to the existing market. However the quality of the cassava starch, in this region of the country is more than acceptable for industrial use. With more than 85% total starch content, the starch produced is easy to cook, presenting good technological aptitudes particularly in brewing where cassava starch could be used as source of sugar during fermentation. With the existing and the potential market, the non-profitable nature of cassava starch production in this region of the country reveals a poor market strategy. Hence, with the aid of projects such as PIDMA, PRASAC and DONATA, the propositions brought out in this work shows that there is room for improvement of the cassava starch value chain. A joint partnership between the local producers and the industrial user will not only enable satisfaction to both ends of the value chain, but it will also be a means to rural and economic development, and weapon against poverty.

In order to complete this work, the following aspects should be considered;

- ✓ Standardize the cassava starch process. Determine the different inputs at each level of the different unit operations and fix standard process parameters.
- ✓ Study the drying parameters that affect the quality of the cassava starch product.
- ✓ Train the women on good hygienic and manufacturing practises.
- ✓ Study the quality of mixed cassava starches.

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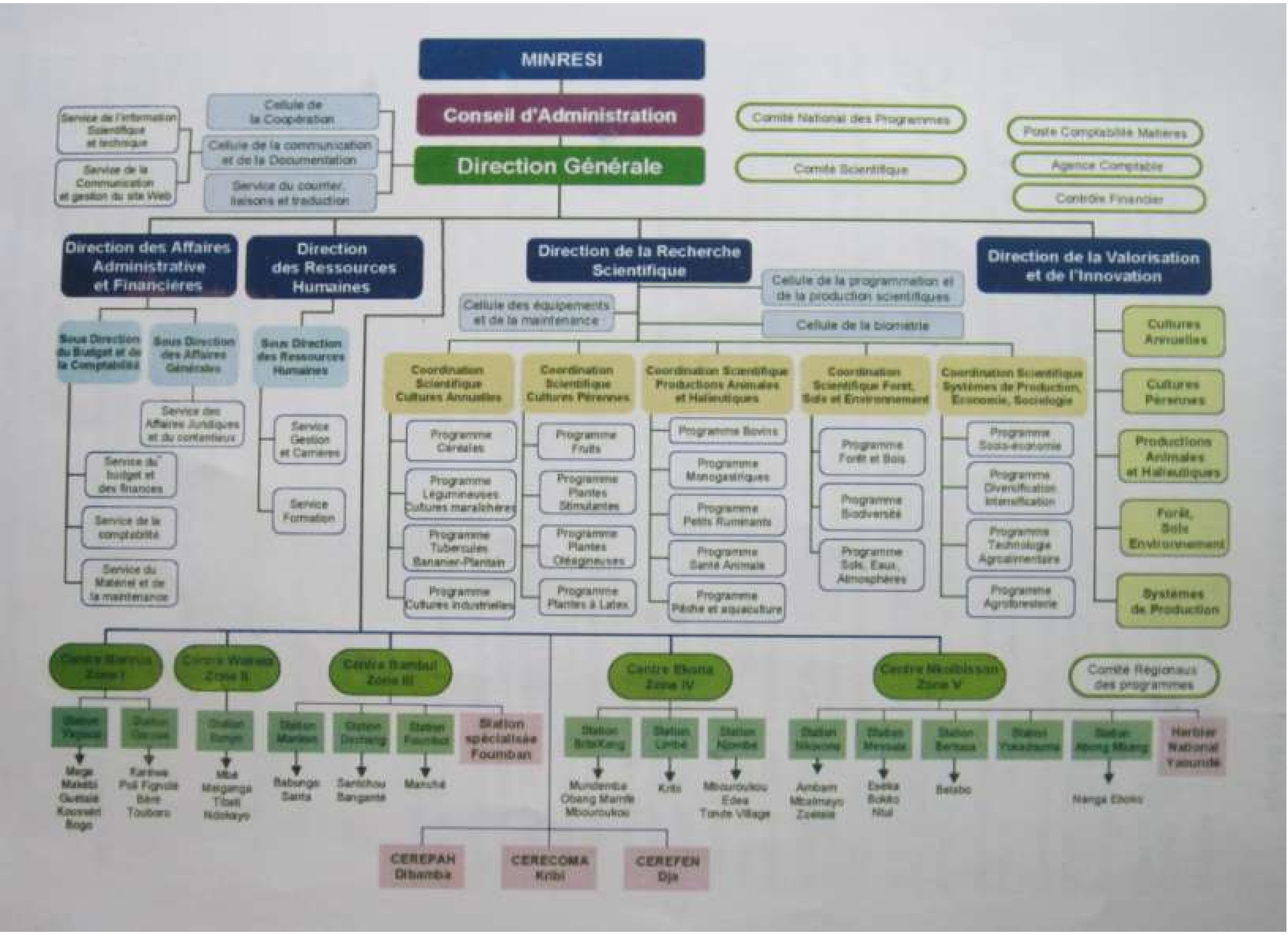
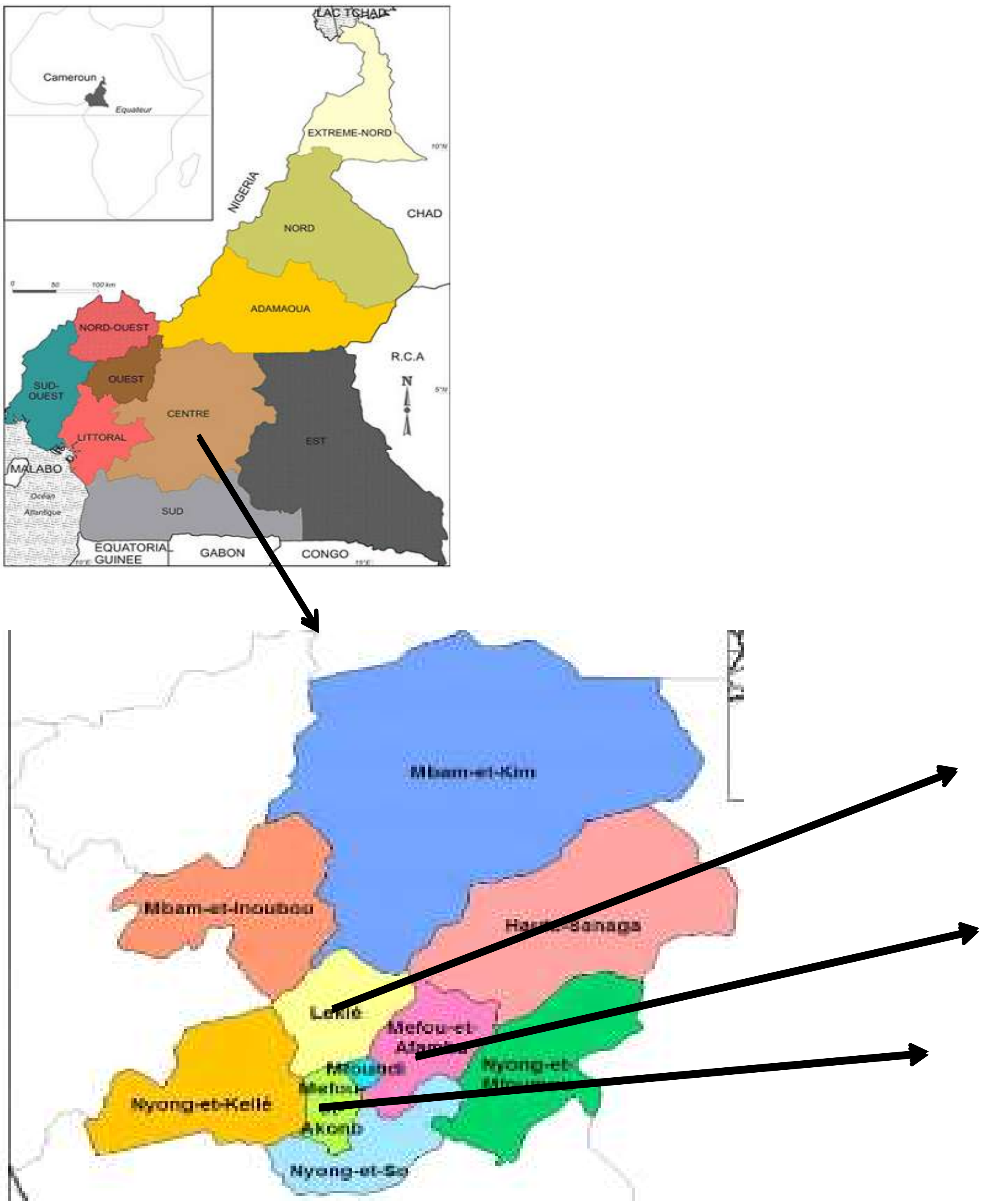
APPENDICES

Appendix 1: Administrative chart of IRAD Yaoundé



Appendix 2: Geographical location of the area of study



Appendix 3: Pictures of the cassava starch processing at Nkong Abok

Picture of peeling operation

Picture of washing operation

Picture of rasping operation

Picture of grinding operation

Picture of second grinding

Picture of mixing operation

Picture of sieving/pressing operation

Picture of sieving/pressing operation

Picture of sedimentation operation

Picture of drying operatio

Appendix 4: Preparation of the cassava root samples for analysis

The cassava roots to be analysed were first peeled with the aid of a knife. Then the cassava roots were washed and then cut into chips. The cassava chips were then dried in an electrical oven at 40°C for 2 days.

After which, the dried cassava chips were then pounded with the aid of a wooden mortar and pestle. The cassava powder was then ground using a small electrical miller. The powder cassava was then used for: water content measurement, total starch measurement, cyanide measurement and ash measurement.

Appendix 5: Expression of result for the dry matter and water content measurement

The dry matter content was calculated using the following formula:

$$DM(\%) = \frac{M2 - M0}{M1 - M0} \times 100$$

Where: M0 = mass of empty nacelle, M1 = mass of sample + empty nacelle before drying, M2 = mass of empty nacelle + sample after drying.

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

$$\%W = 100 - DM$$

Appendix 6: Measurement of total starch and amylose content

N.B: Amylose is insoluble in water, for this reason not all the amylose used dissolved in the 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.

Appendix 7: Table of the standard curve of the total starch measurement

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												

Appendix 8: Expression of results of the total starch and amylose measurement

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.

Appendix 9: Table of the standard curve of amylose content measurement

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												

Appendix 10: Expression of results of the ash content measurement

Total ash per 100 g of starch was calculated as:

$$\%ASH = \frac{M2 - M0}{M1 \times DM} \times 100$$

Where; DM= Dry matter of the sample.

Appendix 11: Expression of results of the water absorption capacity and solubility index measurement

N.B: A small amount of distilled water was used to rinse the centrifugal tubes containing the residues of the wet sediment. The rinsed residues were transferred into the nacelle to assure that all of the wet sediment was collected.

The real water absorption capacity (WAC_r), and the solubility index (SI) were calculated as follows at room temperature (g water/g starch):

$$WAC_r = \frac{M1 - M0}{M2} X\ 100$$

$$SI = \frac{M0 - M2}{M0} \times 100$$

Where M1: Mass of the wet sediment, M0: Mass of sample, M2: Mass of dry sediment.

Mass of wet sediment, M1= W1-W0

Mass of dry sediment, M2 = N1-N0

Appendix 12: Expression of results of the pH and total acidity measurement

The formula used to calculate total acidity is given as follows:

$$A = \frac{C * V}{m * MS} * 100 * 100$$

A: Acidity in mmol/100g of dry matter

C: Concentration of NaOH solution in mmol/ml

V: Volume of NaOH in ml

m: Mass of sample in g

Appendix 13: Procedure for the measurement of the cyanide content

A standard curve was prepared using potassium cyanide (241 mg of KCN in 1 L distilled water, which gives 100 µg/ml equivalent of HCN/mL). This potassium cyanide solution served as a stock solution and from it, another solution of potassium cyanide was prepared, dissolved with a dilution factor of 10. The standard curve was constructed in the range of concentrations from 1 to 10µg/ml equivalent of HCN. This was done by adding the volumes into 10 different test tubes as described in the table below. The standard curve was done with 3 repetitions.

Table of the cyanide standard curve

Reagent/ test tube	**Blank**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
KCN (10µg/ml)	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5
Water (ml)	5	4.5	4	3.5	3	2.5	2	1.5	1	0.5	0
Picrate alkaline solution	5	5	5	5	5	5	5	5	5	5	5
	Heat for 5mins in a boiling water bath.										
O.D at 520nm											

- Expression of results

$$HCN = \frac{50 * x * 100}{m * 2 * MS}$$

HCN = Cyanide content (µg/100g DM or mg/Kg DM)

x = concentration of cyanide obtained from the standard curve

m = mass of sample used

DM= Dry matter of the sample used

Appendix 14: Expression of result for the measurement gelatinization degree

$$Dg = \frac{100(D.OT - D.O0)}{(D.O - D.O0)}$$

Where Dg = Degree of gelatinization

$D.O_T$ = Optical density at the given temperatures

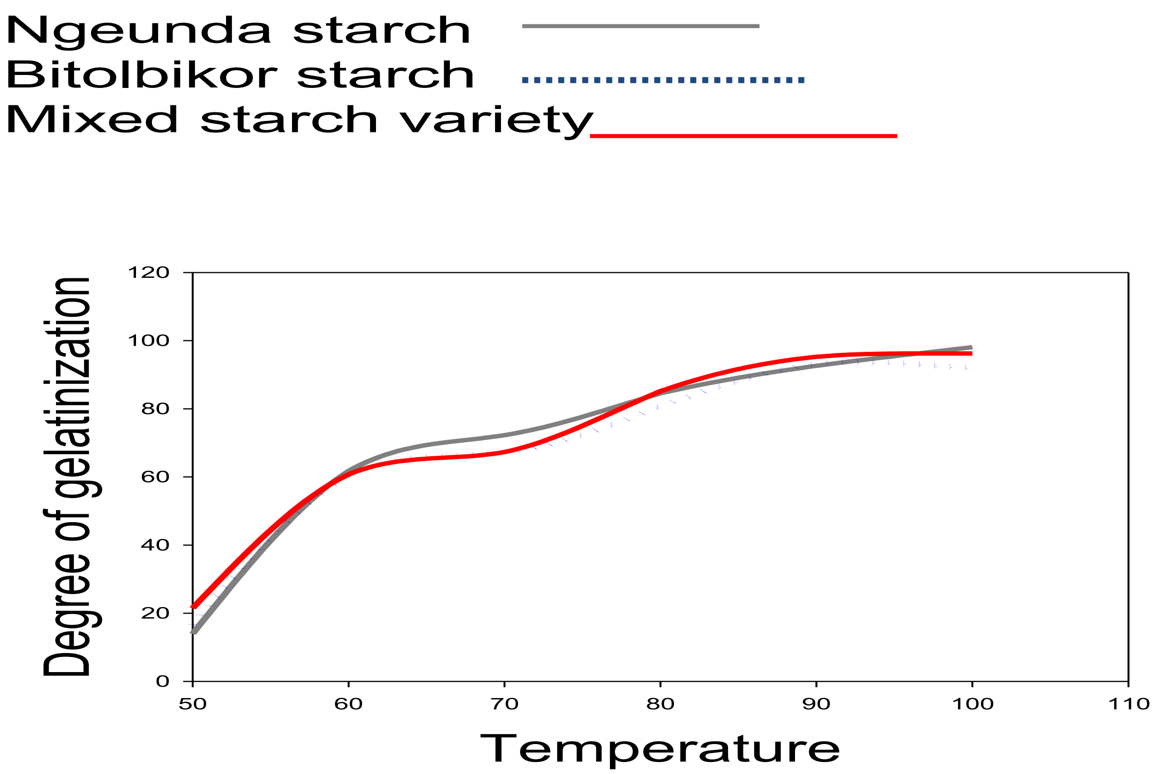
$D.O_0$ = Optical density at temperature 0

D.O = Optical density at complete gelatinization

Appendix 15: Table for the profile of RVA used for pasting properties

Stage	**Temperature and time**
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

Appendix 16: Degree of gelatinization curve



Degree of gelatinization of the starch samples with respect to temperature