DEDICATION

I dedicate this piece of work:

To God Almighty *whose strength is made perfect in my weakness.*

When I am weak, then I am strong. Glory be to You Lord.

To my precious mother, Emshie Francisca Ndenge *for all the sacrifices you have made for me. You have given your all to see me get to this level.*

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To my princess, Muombih Nkeinkoh Joyanne Tangunu. May this serve as an example for you in the years to come.

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LIST OF ABBREVIATIONS AND SYMBOLS

AACC: American Association of Cereal Chemists

AFNOR: '*Agence Francaise de Normalisation*'

ASR: Anaerobic Sulfitoreducers

CFU: Colony Forming Unit

CRFSFS: Comprehensive Reviews in Food Science and Food Safety

DM: Dry Matter

DRC: Democratic Republic of Congo

FAO: Food and Agriculture Organisation

HCN: Hydrogen Cyanide

HNL: Hydroxynitril Lyase

IFAD: International Fund for Agricultural Development

ISO: International Standards Organisation

Mt: Million tons

PQIM: Ponderated Quality Index Means

REPARAC : '*Renforcement des Partenariats dans la Recherche Agronomique au Cameroun'*

TB: Total Bacillus

TC: Total Coliform

TSN: Trypticase Sulfite Neomycin

WC: Water Content

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ABSTRACT

Cassava, scientifically known as *Manihot esculenta* Crantz, is a woody shrub of the *Euphorbiaceae* family. Its culture and consumption face three main drawbacks: low nutritional value, high perishability and potential toxicity. Consequently, it is processed into diverse by-products, one of them being water fu-fu. The commercialisation of water fu-fu faces many constraints amongst which: little or no quality control assurance program and variation in its quality from one processor to the other and with the same processor at different batches of production. Being very popular and highly consumed in most parts of the country, it is necessary that the quality of water fu-fu be ensured. This study was conducted to investigate the effect of the length of retting and the degree of dewatering on the quality of water fu-fu.

One cassava variety, harvested from the same farm was used to produce water fu-fu pastes following a protocol obtained by the use of questionnaires, but having variations in the length of retting and degree of dewatering. The pastes were coded PX,1; PX,2; PX,3(X=number of retting days, 1=most dewatered, 2=averagely dewatered, 3=least dewatered). Physico-chemical analyses were carried out on these different pastes. Water fu-fu samples, FX,1; FX,2; FX,3 were prepared from these pastes and following sensorial analyses, the best fu-fu samples were determined on which microbial analyses were carried out.

During retting, pH dropped to the lowest after 3 days (4.05), then witnessed a slow rise through the fourth and fifth days (4.22 and 4.59 respectively). Continuous dewatering after 3 days retting led to a loss of acidity of the pastes while at 4 and 5 days of retting, continuous dewatering revealed more retention of acidity. Sensorial analyses followed by a calculation of the Ponderated Quality Index Means ranked samples F3,1; F3,2 and F5,3 as the best water fu-fu samples. Microbial analyses carried out on these samples revealed that there was no significant difference in the total Coliform counts. Only sample F3,2 contained anaerobic Sulfitoreducers (1±0.71CFU/g). Samples F3,1 and F3,2 had similar results of total bacillus counts (3.28±0.38 and 3.89±0.27 respectively) while those for sample F5,3 had higher loads of bacilli (7.67± 0.05). These led to the conclusion that in our experiment, water fu-fu from a paste obtained after 3 days of retting with more dewatering was of the best quality.

Key words: Cassava - transformation processes - water fu-fu – quality.

RESUME

Le manioc, *Manihot esculenta* Crantz est un arbrisseau boisé de la famille des *Euphorbiacées.* La culture et consommation du manioc sont confrontées à trois problèmes majeurs : une valeur nutritionnelle faible, un taux de périssabilité élevé et une toxicité inhérente. Par conséquent, le manioc est transformé en de multiples dérivés, en occurrence le 'water fu-fu'. Cependant la commercialisation du 'water fu-fu' reste soumise à plusieurs contraintes : l'absence de programme de contrôle de qualité et la variation de la qualité d'un transformateur à un autre et même au sein d'un même transformateur pour différent batch de production. Très consommé à travers le Cameroun, la qualité du 'water fu-fu' doit être assurée. Ce travail a pour objectif d'évalué l'effet de la durée du rouissage et du degré d'essorage sur la qualité du 'water fu-fu'.

Une variété de manioc, récoltée dans le même champ a été utilisé pour produire les pates de 'water fu-fu', en accord avec les protocoles obtenus des questionnaires, mais avec des variations de durée de rouissage et de dégrée d'essorage. Les pates ont été codées PX,1 ; PX,2 ; PX,3 (X=nombre de jour de rouissage, 1=très essoré 2=moyennement essoré, 3= faiblement essoré). Les analyses physico-chimiques ont été menées sur ces différentes pâtes. Les échantillons de 'water fu-fu', FX,1 ; FX,2 et FX,3 ont été préparés à partir des pâtes et suivant les analyses sensorielles, les meilleures échantillons de fu-fu ont été déterminés et des analyses microbiologiques ont par la suite été mener.

Durant le rouissage, le pH chute au plus bas après 03 jours (4.05), ensuite le quatrième et le cinquième jour, le pH augmente légèrement (respectivement 4.22 et 4.59). Un essorage continu après trois jours de rouissage entraine une perte d'acidité de la pâte, pourtant un essorage continu à 4 et 5 jours de rouissage montre plus de rétention d'acidité. Les analyses sensorielles suivis du calcul de la moyenne de l'indice de qualité pondéré classe les échantillons F3,1 ; F3,2 et F5,3 comme les meilleures échantillons de 'water fu-fu'. L'analyse microbiologique révèle qu'il n'y a pas de différence significative dans la numération des coliformes totaux. Seul l'échantillon F3,2 contient des sulfitoréducteurs anaérobies (1±0.71 CFU/g). Les échantillons F3,1 et F3,2 ont des résultats similaires en ce qui concerne les Bacillus totaux (respectivement 3.28±0.38 et 3.89±0.27). Par contre l'échantillon F5,3 enregistre le plus haut taux de Bacillus (7.67±0.05). Parvenu au terme de notre travail, nous pouvons dire que le 'water fu-fu' obtenu d'une pâte de 03 jours de rouissage et très essoré était d'une meilleure qualité.

Mots clés : Manioc - opérations de transformation -'water fu-fu'- qualité

Roots and tubers are the base of feeding for the population of Central Africa (Tricoche *et al.*, 2008) with cassava, (*Manihot esculenta* Crantz), -a woody shrub of the *Euphorbiaceae* family- being one of such. Also called "mandioca", "manioc", "yucca", or "tapioca", it is a major staple root crop in many tropical and subtropical developing countries, especially in West Africa, (Montagnac *et al.*, 2009). Today it is an important staple food crop and animal feed for millions of people and animals in the tropical and subtropical areas of Africa, Asia and Latin America (Nwabueze and Odunsi, 2007, Etudaiye *et al.*, 2009). Cassava is primarily cultivated for auto-consumption (Tricoche *et al.*, 2008). Smallholder farmers often commercialise only a minor part of their production despite aggressive competition for cassava industrial use, particularly from Asian countries. However, as far as the industrial use of cassava is concerned, limited progress has been made in some African producing countries like Benin, Sierra Leone, and Cameroon (International Fund for Agricultural Development, IFAD, 2006).

Cassava is the fourth most important food source of carbohydrates in the tropics after rice, maize and sugarcane (Blagbrough *et al*., 2010). Approximately 500 million people depend on it as a major carbohydrate (energy) source, in part because it yields more energy per hectare than other major crops (Montagnac *et al.*, 2009). Cassava is very poor in lipids -0.2 to 0.5%- and in proteins –approximately 1%-with its available proteins referred to as being of "bad quality" since they contain very little Methionine which is an indispensable amino acid (Laure, 1981). Protein from other sources is therefore needed if cassava has to be part of a balanced diet (Westby, 2002).

The use of cassava as food is not only limited by its low protein content but also by its perishability and potential toxicity (Irtwange and Achimba, 2009). In addition to its low nutritional value, cassava unfortunately contains toxic compounds known as cyanogenic glucosides (Linamarine and Lotaustraline), which, together with their breakdown products (Cyanohydrins and free HCN) formed during processing, can cause health problems. Acute intoxication, manifested through vomiting, dizziness or even death, can occur under very rare conditions (Westby, 2002). Harvested cassava is highly perishable, so, in order to fight against post-harvest losses and to reduce its toxicity, harvested cassava is generally processed before consumption into diverse by-products, which become available all year round for household consumption.

The commercialisation of cassava and its by-products is an economic activity which generates revenue for the upkeep of many households (Mbairanoji, 2007), yet it faces many constraints amongst which: little or no quality control assurance program identified with any of the products; variation in the quality of the products from one processor to the other and with the same processor at different batches of processing, (Sanni *et al*., 2003). This leads to poor sales, potentially toxic products, short shelf life and no industrialization. Water fu-fu is one of such products. It is consumed alongside a green vegetable, 'eru' (*Gnetum africanum* Welw) and its popularity has spread to attain national dimensions in Cameroon (Abia *et al*., 2007).

Looking at the popularity and high frequency of consumption of water fu-fu in most parts of the country, the rate at which its consumption is gaining grounds both at national and international levels, the constraints involved in its production and the resulting sanitary risks, a necessity to ensure the quality of this water fu-fu is imperative. During the transformation process, there exist critical unitary operations such as fermentation and dewatering which can affect the quality of water fu-fu. As such, a mastery of these processes could lead to the improvement of the quality of water fu-fu as well as increase its storability, so that industrial production and exportation can be facilitated. The main goal of this study is to assess the impact of the critical unitary operations during the production of water fu-fu on its quality. This will be done by:

- Investigating on the different unitary operations used by local producers of water fu-fu in order to determine the production process as well as the main variations.
- Investigating physical and biochemical parameters influencing the consumer based quality assessment of water fu-fu (physico-chemical, sensorial and microbiological).
- Assessing the impact of variations at the critical points in the production process on the most important consumer based quality parameters of water fu-fu.

I. GENERALITIES ON CASSAVA

Cassava, scientifically known as *Manihot esculenta* Crantz, is a pluri-annual tropical woody shrub with tuberous adventitious roots which when cultivated can attain a height of one to three meters and four to five meters if not harvested (Favier, 1977; Djoulde, 2005; Nassar and Ortiz, 2007). The stem of diameter, two to three centimeters carries alternate bilobed leaves with white latex, and this plant belongs to the *Euphorbiaceae* family (Favier, 1977; Djoulde, 2005). The tuber weighs between 200g and 3Kg and in certain circumstances, can attain a length of 1m and weigh 20 to 25Kg (Favier, 1977), **(Picture 1).** Cassava is essentially cultivated for its roots, which form a base for the feeding of many populations, especially Africans. The leaves and occasionally the stems can be sometimes used in the preparation of food salt (Laure, 1981).

Cassava is scientifically classified as follows:

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

Depending on the country, it has different names: Cassava in English speaking countries of Africa, "Tapioca" (Malaysia, Indonesia, India and the Pacific), "Manihot", "Mandioca" and "Uca" in Latin America, "Bafilinapaka" ("Republique Malgache"), "Bankye" in Ghana, "Agbeli" in Togo and "Mandioka" in Gambia (Laure, 1981).

Picture 1: *Young cassava plant and cassava roots* (*By Njang*)

A. ORIGIN AND INTEREST OF CASSAVA

1. ORIGIN

The cassava plant is original to the Brazilian Amazone Rainforest. It was introduced into West Africa by the Portuguese and has been adapted to the African and Asian continents, who today are the main producers of this raw material, (Pierre Silvestre, 1989; Maieves *et al*., 2011). It was later introduced into Africa and Asia where due to its high starch content, it is a staple food for more than 500 million people (Blagbrough *et al*., 2010) and forms the subsistence base of the poorer populations in the marginal areas of these continents (Series on the Safety of Novel Foods and Feeds, 2009).

2. INTEREST

Cassava is a nutritionally strategic famine crop and could support food security in areas of low rainfall. Mature roots are able to survive for a long time without water and still retain nutritional value (Montagnac *et al*., 2009). The plant is resistant to certain conditions of dryness, which certain cereals, notably maize and rice cannot support. This ability to grow on marginal soils has enabled its spread into tropical and sub-tropical zones (Amani *et al*., 2007). Cassava can survive difficult climatic conditions and has easy and well mastered transformation processes (Djoulde, 2005).

Cassava roots can be left in the soil and be progressively harvested in order to cut down the risk of subsequent food contamination. Another characteristic of the plant is its ability to protect itself against certain pests, due to its high cyanogenic glucoside content (Amani *et al*., 2007).

Because cassava is drought-tolerant and its mature roots can maintain their nutritional value for a long time without water, cassava may represent the future of food security in some developing countries (Montagnac *et al*., 2009). Also, with increasing urbanization rates, cassava products can offer a response to the growing demand for food products which will otherwise require an increase in food imports (IFAD, 2006).

B. PRODUCTION, CULTIVATION AND USE OF CASSAVA ROOTS

1. PRODUCTION

The production of cassava has gradually gained grounds especially in tropical and sub-tropical Africa with Nigeria becoming the highest producer. The five countries with the highest production of cassava in 2006/2007 were Nigeria (40.1 million tones [Mt]), Brazil (26.6 Mt), Thailand (24.7 Mt), Indonesia (20Mt) and the Democratic Republic of Congo, DRC, (15Mt) (FAOSTAT, 2009). Cameroon ranked 19th on the classification list with national production estimated at more than two million tons (Mt) of cassava roots per year (Mandjoung, 2007). World production of cassava roots was estimated to be 184 Mt in 2002, rising through 200 Mt in 2005 (Amani *et al.,* 2007), 228Mt in 2007 to 230 Mt in 2008 (FAO, 2008). In the world, cassava production occupies fifth position after maize, rice, wheat and irish potatoes. In the tropics, it occupies third position after rice and maize (Amani *et al*., 2007). Africa now produces more cassava than the rest of the world combined and the largest nations are Nigeria, (35% of total African production and 19% of world production), DRC, (19% of African production), Ghana (8%), Tanzania (7%) and Mozambique (6%), (Hillocks *et al*., 2002). Asia and South America and the Carribeans represent 32% and 16% of world production respectively (Amani *et al*., 2007).

2. CULTIVATION

Cassava is grown widely in several parts of the world especially in the tropical regions and constitutes a significant proportion of the diet of the population (Dziedzoave *et al*., 2000; Tetchi, 2012). It is mostly cultivated in tropical areas because of its high suitability for growing in marginal climatic and soil fertility conditions with a high productivity per unit area (Reginier *et al*., 2010). Cultivation is carried out throughout the lowland tropics typically between 30^{o}N and 30^{o}S of the equator, in areas where the annual mean temperature is greater than 18^{o}C (Nassar and Ortiz, 2007). In Africa, cassava is usually grown in mixed stands with other crops such as maize, beans (Laure, 1981; Hillocks *et al.,* 2002), cocoyams and sorghum (Hillocks *et al.,* 2002).

Its propagation is with the use of stem cuttings (vegetative propagules), (Series on the Safety of Novel Foods and Feeds, 2009; Bradbury and Denton, 2010). It requires very little attention and little fertilizers and is cultivated during the rainy season (Laure, 1981). Cassava is easy to grow (Cardoso *et al.,* 2005) and gives reasonable yields even in poor soils in the absence of fertilizer (Bradbury and Denton, 2010). However, fertilizer is often required for the plant to reach maximum production potential (Hillocks *et al.,* 2002). Cassava is one of the most drought-tolerant crops and can be successfully grown on marginal soils, giving reasonable yields where many other crops do not grow well (Asegbeloyin and Onyimonyi, 2007).

Cassava culture can face the problems of pathogens, diseases and pests which considerably reduce its yields. They include: elegant grasshopper, root mealybug (Hillocks *et al*., 2002), Blight Leaf Spot (BILS), Brown Leaf Spot (BLS), White Leaf Spot (WLS), (Wydra and Verdier, 2002), Cassava Brown Streak Virus Disease (CBSD), Nematodes, root and tuber scale (Nassar and Ortiz, 2007), root rots (Hillocks *et al*., 2002; Wydra and Verdier, 2002), Cassava Green Mites (CGM), cassava mealy bug, Cassava Mosaic Virus (CMV), Cassava Bacterial Blight (CBB), (Hillocks *et al*., 2002; Nassar and Ortiz, 2007), Cassava Anthracnose Disease (CAD) (Hillocks *et al*., 2002; Wydra and Verdier, 2002; Nassar and Ortiz, 2007).

Despite all these, cassava is cultivated first for its roots, then for its young leaves, which are consumed as vegetables.

3. USES OF CASSAVA ROOTS

Cassava is used the world over: for human consumption, as animal feed, in industries as raw material for many derived sugar products such as glucose, maltodextrines, mannitol and ethanol. Approximately 57% of world cassava root production is used for human consumption, 32% for animal feed and industrial purposes, and 11% is waste material. It is also used as raw material for producing cassava starch, which is an important raw material in food processing, paper, textile and adhesive manufacturing and in the oil drilling industry (Nassar and Ortiz, 2007). In Africa, the majority of cassava produced (88%) is used for human consumption, with over 50% used in the form of processed products. Its uses as animal feed and for starch are very minor (Westby, 2002).

Many varieties of cassava exist which can be regrouped in two main ways:

- Depending on the maturity of the roots, we have two main categories:
    - ***Manihot aipi* (the sweet variety)** which is cultivated for the local consumption of the tubers (that is cooked by immersion in boiling water). Their tuberous roots mature in 6 to 9 months and deteriorate rapidly if not harvested soon after maturity.
    - ***Manihot palmate* (the bitter variety)** which is mostly used for food after undergoing a process of fermentation. They require 12 to 18 months to mature and will not deteriorate greatly if not harvested for several months. (Djilemo, 2007; Nassar and Ortiz, 2007; Sarkiyayi and Agar, 2010).
- Depending on the level of toxicity, we have three main categories:
    - **The innocuous or non-toxic variety** which contains less than 50mg of HCN per Kg of fresh peeled roots,
    - **The moderately toxic variety** which contains 50 to 100mg of HCN per Kg of fresh peeled roots,

- **The extremely toxic variety** which contains over 100mg of HCN per Kg of fresh peeled roots. (Ameny, 1995; Jansz and Inoka, 1997 ; Kobawila *et al*., 2005; Amani *et al*., 2007).

Cassava is grown in areas where mineral and vitamin deficiencies are widespread, especially in Africa. A marginal nutrient status increases the risk of morbidity and mortality. Therefore, improving the nutritional value of cassava could alleviate some aspects of hidden hunger, that is, subclinical nutrient deficiencies without overt clinical signs of malnutrition (Montagnac *et al*., 2009).

C. NUTRITIONAL VALUE AND TOXICITY OF CASSAVA ROOTS

The use of cassava as food has three main drawbacks: its perishability, low protein content and potential toxicity (Irtwange and Achimba, 2009).

1. NUTRITIONAL VALUE

According to Laure (1981), cassava roots have a calorific value which varies between 125 and 140Kcal for 100g of fresh and peeled cassava. It is mostly made up of carbohydrates, which make it an energy-giving food. Though rich in carbohydrates and essentially starch, they are poor in proteins and very poor in lipids (fats) (Amani *et al*., 2007). More so, its proteins are said to be of "bad quality" since they contain very little Methionine which is an essential amino acid (Laure, 1981). It does not contain gluten, the causative agent for celiac disease (Vogelmann *et al*., 2009). On the other hand, it is poor in minerals (Calcium, Iron, and Phosphorus) and vitamins (which are even less in cooked tubers). For these reasons, cassava needs to be associated to other foods rich in lipids and proteins from other sources if it has to be part of a balanced diet (Laure, 1981; Westby, 2002). In **table 1** below, the nutritional, mineral and vitamin contents of cassava is reported.

On the other hand, cassava leaves are very rich in proteins and vitamins, especially vitamin C (Laure, 1981). **Table 2** below shows the nutritional composition of cassava leaves in comparison with the roots.

***Table 1**: Composition of main nutrients, minerals and vitamins in 100g of raw cassava*

Main nutrients in 100g of raw cassava

Nutrient	Water	Energy	Protein	Carbohydrate	Sugars	Fiber	Cholesterol
Amount	59.680g	160kcal	1.360 g	38.060 g	1.700g	1.800g	0.000 mg

Minerals in 100g of raw cassava

Name	Ca	Cu	F	Fe	Mg	Mn	P	K	Se	Na	Zn
Amount	16mg	0.1µg	0.0mg	0.27mg	21mg	0.384mg	27mg	271mg	0.7µg	14mg	0.34mg

Vitamins in 100g of raw cassava

Vit	A	D	E	K	B1	B2	B3	B6	C	Folate
Amount	1µg	0.0IU	0.19mg	1.9µg	0.087mg	0.048mg	0.854mg	0.088mg	20.6mg	27mg

(Drawn up from Food.VegTalk.ORG) Nutrients in raw cassava

***Table 2:** Nutritional composition of cassava leaves and roots*

	Leaves	**Roots**
Water	80%	62 to 68%
Carbohydrates	7%	35% (with 20-25% starch)
Lipids	1%	0.3%
Proteins	6%	Approximately 1%
Vitamin C	200mg/100g	35mg/100g
Vitamin B1	0.2mg/100g	Negligible
Vitamin B2	0.3mg/100g	Negligible

(Source: Onwueme, 1978)

2. TOXICITY

One major factor that limits or affects the utilization of cassava as a food for man is its content of the toxic hydrogen cyanide in both free and bound forms (Edijala *et al*., 1999). The free form is essentially made up of hydrogen cyanide, which is highly concentrated in the bark (this part is eliminated during peeling). The bound form is in the form of cyanohydrins and cyanogenic glucosides. Cassava roots and leaves contain cyanogenic glucosides - Linamarine (93 to 96%) and Lotaustraline or methyl linamarine (4 to 7%) - which, together with their breakdown products (cyanohydrins and free HCN) formed during processing and chewing, can cause health problems (Amani *et al*., 2007; Nyirenda *et al*., 2010). Indeed, cassava roots and leaves should not be consumed raw. The consumption of low amounts of these substances is toxic and an accumulation will lead to long term intoxication. Cassava and its by-products such as cassava starch contain large amounts of cyanogens and may cause cyanide poisoning, manifested as vomiting, dizziness, nausea, stomach pains, weakness, headache and diarrhea and occasionally, death (Mlingi *et al*., 1995; Westby, 2002; Kobawila *et al*., 2005)

The highly perishable nature of harvested cassava and the presence of cyanogenic glucosides call for immediate processing of the storage roots into more stable and safer products (Hillocks *et al*., 2002). Irtwange and Achimba (2009) reported that processing methods have been devised for this purpose.

II. THE TRANSFORMATION OF CASSAVA

Processing provides a means of producing shelf-stable products (thereby reducing losses), adding value at a local level and reducing the bulk to be marketed (Sanni *et al*., 2007). Cassava is consumed by humans as fresh processed roots, fermented roots, cassava flour-based products or cooked leaves (Series on the Safety of Novel Foods and Feeds, 2009).

A. PROCESSES INVOLVED IN LOCAL CASSAVA TRANSFORMATION

Cassava processing involves a combination of step-wise unitary operations. The number of steps required and the transformation sequence depends on the product being made. Some of these unitary operations include:

- **Peeling:** This helps to eliminate the bark of the cassava root from the cortex in order to recuperate the central cylinder, which is the consumable or transformable part (Mandjoung, 2007).

- **Washing:** This is done in order to eliminate mud and particles of sand (Mandjoung, 2007). Washing is done severally and the number of times depends on the individual.

- **Chipping:** This involves slicing the cassava roots in order to obtain smaller dimensions. This helps to hasten the process of fermentation by favouring contact between linamarin and the enzyme linamarase which is naturally present in cassava.

- **Fermentation (Retting):** It consists of steeping the roots into water for a few days. The aim of retting is to soften the roots, degrade the endogenous cyanogenic compounds and develop the acidic flavour (through the production of organic acids and the drop in pH), (Ampe *et al*., 1994). Almost all by-products of cassava transformation undergo the process of fermentation.

- **Dewatering:** This is a pre-drying operation. It can either be done manually or mechanically (Mandjoung, 2007). It leads to the loss of inorganic acids in the pressed liquor, consequently, pH and total titratable acid values of the paste increase and decrease respectively (Obilie *et al*., 2004).

- **Cooking:** This operation helps to favour the evaporation of the volatile HCN and at the same time confer on the final product certain organoleptic characteristics. It also reduces 90% free cyanide and 55% bound cyanide, likely improving flavour (Agatemor*,* 2009).

The mode and sequence of carrying out each of these operations varies from one country to the other and the result is the existence of a variety of by-products of cassava transformation. It also generates a wide range of intermediate products which can be either sold or stored until the need arises for conversion into the final product.

B. BY-PRODUCTS OF CASSAVA TRANSFORMATION

Cassava is transformed into a wide variety of products, especially in Africa and South America (Westby, 2002). Both the roots and leaves are used for human consumption. The food products for consumption include: 'bobolo', commonly known as 'baton de manioc', gari -fermented pastes- (fu-fu), 'mintoumba' (spiced pastes) (Amani *et al*., 2007; Mandjoung, 2007), flour, attiekie, tapioca, sugars, food starch, "kwem", kokonte, mapoka (Amani *et al*., 2007). Other food types from fermented cassava in Cameroon are koum-koum, Myondo and water fu-fu, **(Picture 2**). **Figure 1** below represents the flow chart for the production of some common cassava products.

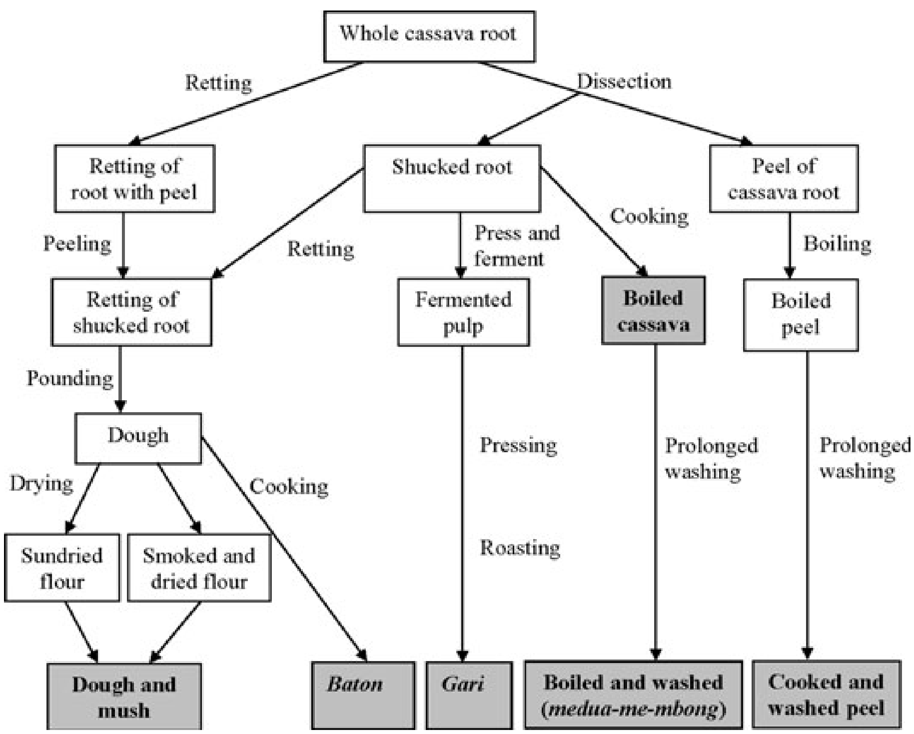


Figure 1*: Different processing techniques for whole cassava root. The edible forms of cassava roots are shaded in gray (source: Favier 1977).*

Other processing techniques as presented by Essia Ngang, 2008 are shown on **appendix 3**.

Amongst the fu-fu products, we have 'amala' of Nigeria, 'toh' of Guinea, 'ugali' and 'atap' of Uganda and Tanzania, 'ubugali' of Rwanda, 'funge' of Angola and 'water fu-fu' of Cameroon.

Picture 2: *Samples of Cassava by-products* *(By Njang)*

III. THE CASE OF "WATER FU-FU"

According to Djoulde (2005), fu-fu is a food substance which is pounded and boiled to give a thick paste. Water fu-fu is cooked cassava dough, made from a double fermented cassava paste and usually eaten with a vegetable soup, "eru". The main component of the soup is eru (*Gnetum africanum* Welw) and the dish is popularly eaten in Cameroon and neighbouring Nigeria. The two components of the dish are prepared separately but served together, **(Picture 3)**. Previously, the dish was associated with a particular tribe, (the Banyangs) as it was their staple meal. But in recent years, almost all ethnic groupings, especially those from the South West and North West

Provinces (now Regions) have learned to cook and eat "water fu-fu and eru". Its popularity has spread to attain national dimensions (Abia *et al*, 2007).

Picture 3: *Plate of water fu-fu and eru* *(ByNjang)*

A. THE PRODUCTION OF "WATER FU-FU"

After harvesting and peeling, the cassava roots, either left whole or cut into smaller pieces are steeped in water for 3 to 5 days. When they are soft, they are removed and passed through a colander or sieve to remove the fibers. They are then firmly tied in bags between sticks and allowed to dewater until a thick paste is obtained. The paste can then be stored and prepared when needed by dissolving in a little water and cooking under gentle heat for 30 to 45 minutes. **Figure 2** below represents the protocol for the production of water fu-fu according to Essia Ngang, 2008.

Cassava roots
↓
Peeling/washing
↓
Cutting/whole
↓
Retting
↓
Removal of fiber
↓
Dewatering under static pressure, 2-3hours
↓
Grinding
↓
Cassava paste
↓
Cooking
↓
Water fu-fu

***Figure 2**: Production of water fu-fu according to Essia Ngang, 2008*

***Picture 4:** Cassava retting, dewatering and water fu-fu*

(By Njang)

B. THE QUALITY OF FOOD

Intuitively, quality refers to "the value" of something. Irtwange and Achimba (2009) define it as the degree of excellence and acceptance while the French standards agency, AFNOR sees it as the ability of a product to satisfy its users. In a more complete manner, the International Standards Organization (ISO) defines quality as the properties and characteristics of a product or service which confer on it the ability to satisfy the expressed or implicit needs of all the users. In the case of food substances, the final users are the consumers. The quality of food is therefore defined by the following components, see **figure 3**

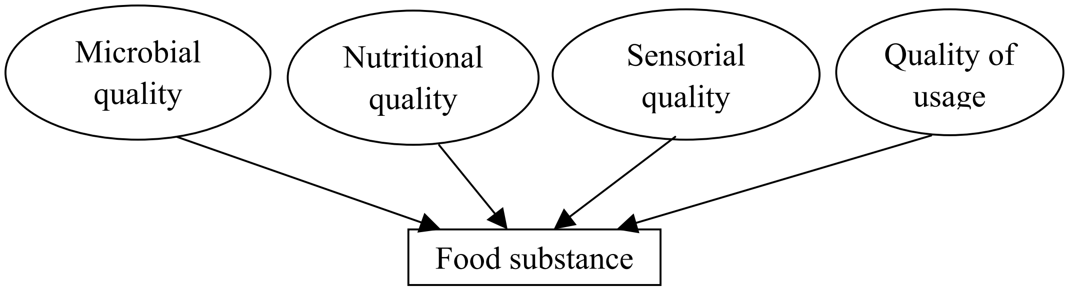


Figure 3: *Components of the quality of food*

These qualities can be summarized in French as the **4S**: "**S**écurité, **S**anté, **S**aveur, et **S**ervice".

1. MICROBIAL QUALITY: (S1-Securité)

Also referred to as the hygienic quality, it reflects the degree of sanitation during manipulation (transportation, transformation, preservation). This quality depends on the presence of microbes and/or their toxins. Two parameters can be used to appreciate the microbial quality of food:

- The Total Aerobic Mesophilic Floral (TAMF) count: It is used to evaluate the number of Colony Forming Units (CFU) present in a given product or on a given surface. It is an indicator of the general hygiene of the food.
- Total and Fecal Coliforms such as *Escherichia coli,* whose presence in food indicate either fecal contamination or insufficient thermal treatment.

Water fu-fu undergoes thermal treatment for about 45 minutes in order to move from the paste to the final product. This can lead us to say that water fu-fu has a low degree of contamination on condition that it is properly preserved after preparation and consumed shortly after.

2. NUTRITIONAL QUALITY: (S2-Santé)

This refers to the ability of food to provide the body with the required nutrients, both major (carbohydrates, proteins and lipids) and minor (vitamins and minerals).

Water fu-fu is made from cassava roots which are a very rich source of carbohydrates and some food fibers but are poor in proteins, lipids and vitamin A (Favier, 1977). For this reason, water fu-fu needs to be eaten in association with foods rich in proteins and lipids in order to make a balanced diet (Laure, 1981; Westby, 2002)

3. SENSORIAL QUALITY: (S3-Saveur)

This is the ability of the food to satisfy the five human senses. Parameters which make up this quality include colour, texture, aroma, taste, flavour, and savour. Given the diversity of human preferences, this quality varies depending on the choice of the consumer.

4. USAGE QUALITY: (S4-Service)

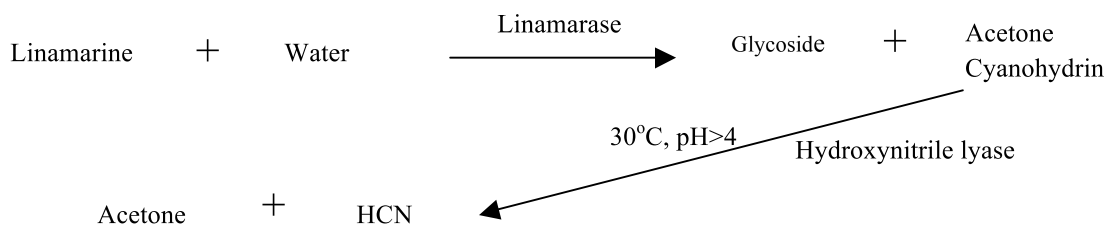
This refers to the preservability, affordability and ease of transportation and utilisation of the food product. Healthy, complete and delicious food will not be sold if it is too expensive, difficult to find, difficult to prepare and impossible to preserve.

C. FACTORS AFFECTING THE QUALITY OF "WATER FU-FU"

1. DURATION OF RETTING

Cassava retting is a spontaneous lactic acid fermentation carried out in Central Africa, characterized by the significant breakdown of cassava cell walls, the degradation of endogenous cyanogens and the development of flavours and taste. The softening of cassava roots is due to the lysis of plant cell walls made up mainly of pectin and cellulose, (Brauman *et al*., 1995). This happens under the action of macerating enzymes – α-amylases, β-glucosidases and pectinases, (pectinesterase and pectate lyase) - (Brauman *et al*., 1995; Djoulde *et al*., 2005).

Retting helps to eliminate more than 90% endogenous cyanogenic compounds in cassava roots (Brauman *et al*., 1995). The enzyme responsible for this breakdown is Linamarase, β-D glucoside glucohydrolase, (EC. 3.2.1.21), (Jansz and Inoka, 1997) which is highly concentrated in the plant cell wall. A drop in the pH of the roots helps to accelerate the hydrolysis of cyanogenic glucosides by promoting the spontaneous breakdown of cyanohydrins to give free hydrogen cyanide which is both volatile and water soluble (Agbor-Egbe *et al*., 1995). The drop in pH also considerably limits the development of undesired or pathogenous micro organisms (Brauman *et al*., 1995). Following the disruption of the plant cell wall or in the presence of water, the enzyme linamarase comes in contact with its substrate, linamarine (found in the vacuoles of the cytoplasm), breaking it down to glucose and acetone cyanohydrin. In a second instance, acetone cyanohydrin either spontaneously (at $pH > 4$ and temperatures above 30^oC) or under the catalytic action of Hydroxynitril Lyase (HNL) is further degraded into acetone and hydrogen cyanide (Montagnac *et al*., 2009).



Equation for the breakdown of linamarine (adapted from Amani *et al.,* 2007).

Irtwange and Achimba (2009) report that the amount of HCN in cassava decreases with increase in the duration of retting. However, extremely prolonged retting leads to the loss of dry matter and the obtention of water fu-fu with a very acidic taste. Solid state fermentation (retting) can be carried out with the introduction of an artificial inoculant. The aim of using this inoculant is to reduce retting time and improve the texture, colour and flavour of the cassava dough (Ellis *et al*., 1997).

During retting, there is also acidification of the cassava dough through the production of organic acids and this is responsible for the typical flavour and sour taste of the final products (Obilie et al., 2004). This characteristic is partly due to the production of lactate and acetate produced by lactic acid bacteria, and butyrate produced by clostridia (Brauman *et al*., 1995). Agatemor, (2009) reports that retting contributes to the colour and flavour of the product and that the removal of cyanide likely improves flavour.

Given that most by-products of cassava transformation undergo fermentation, and given that the degree of cassava retting greatly affects the quality of water fu-fu, the duration of retting needs to be standardised in an attempt to harmonize and optimize the quality of the water fu-fu obtained.

2. DEGREE OF MASHING

Methods that use grating and crushing are very effective in removing cyanide because of the intimate contact in the finely divided wet parenchyma between linamarin and the hydrolising enzyme linamarase, which promotes rapid breakdown of linamarin to hydrogen cyanide gas that escapes into the air (Cardoso *et al*., 2005).

3. DEGREE OF DEWATERING

Dewatering leads to the loss of organic acids in the pressed liquor and consequently pH and Total Titratable Acidity values increase and decrease respectively (Obilie *et al*., 2004). Removal of more water from the paste leads to the elimination of more of the dissolved HCN, improving on the security of the paste. Interest in the degree of dewatering is because of the fact that a more dewatered paste will have a longer shelf life, bringing in the possibility of industrial production and exportation.

4. TEMPERATURE AND DURATION OF COOKING

Higher cooking temperatures will help to kill bacteria especially those which may have been picked up due to poor hygienic conditions during transformation. The presence of these bacteria is verified following a Total Coliform count. In addition, higher temperatures will help to destroy spores which may be found in the food, which if not destroyed will get activated and proliferate when temperatures become conducive for them.

On the other hand, as cooking time increases, the starch molecules absorb more water and get more hydrolyzed. This results in a change of the colour of water fu-fu from whitish to cream white.

I. IDENTIFICATION OF DIFFERENT PROCEDURES FOR THE LOCAL TRANSFORMATION OF CASSAVA ROOTS INTO WATER FU-FU AND ITS CONSUMPTION

A. MATERIAL

This diagnosis was done through informal and formal interactions with producers and consumers of water fu-fu. Semi structured questionnaires (**Appendix 1**) were designed and used to determine opinions of respondents on the different procedures employed.

B. METHODS

The informal interactions involved the localisation of production and consumption sites followed by contacts and visitation of water fu-fu producers and consumers. In a more formal manner, questionnaires were administered, through which general aspects concerning the production of water fu-fu as well as the preferences of the consumers were obtained.

After presenting the objectives of the questionnaire, those who consented to responding were guided on how to fill out the form. Sensorial preferences were evaluated based on a five point hedonic scale adapted from Agatemor*,* 2009. The degree of importance of each quality parameter was determined by rating on a scale of 10 with 1 representing not important to 10 corresponding to very important.

1. PERIOD OF OPERATION AND NUMBER OF ACTORS

The questionnaires were administered from February to April 2012 and a total of 128 cassava producers and consumers were questioned.

2. ANALYSIS OF RESULTS

The results obtained after verification and validation, were analysed using the Sphinx Plus^2-Edition Lexica-V5 software.

II. TRANSFORMATION OF CASSAVA ROOTS INTO WATER FU-FU

A. MATERIAL

The following material was used:

- Cassava roots aged 16 months. These roots were harvested from a village called Nkolmeseng in the Center region of Cameroon. They were packed in a fiber bag and immediately transported to the microbiology laboratory of the University of Yaoundé I where the process of transformation into water fu-fu immediately began.
- Inert material which consisted of laboratory glassware, plastic buckets, a knife, salt bags for dewatering, a colander, a pot and a spatula.

B. METHODS

The protocol used for the transformation of cassava roots into water fu-fu was derived from that used by the majority of the respondents (73.33%, obtained from the questionnaires). This transformation process comprised of many unitary operations which include peeling, washing, retting, defibering, dewatering, reconstitution of paste (dissolving in water and mixing to remove lumps) and cooking. **Figure 4** below represents the transformation process into which the different analyses to be carried out at the different stages of manipulation have been indicated.

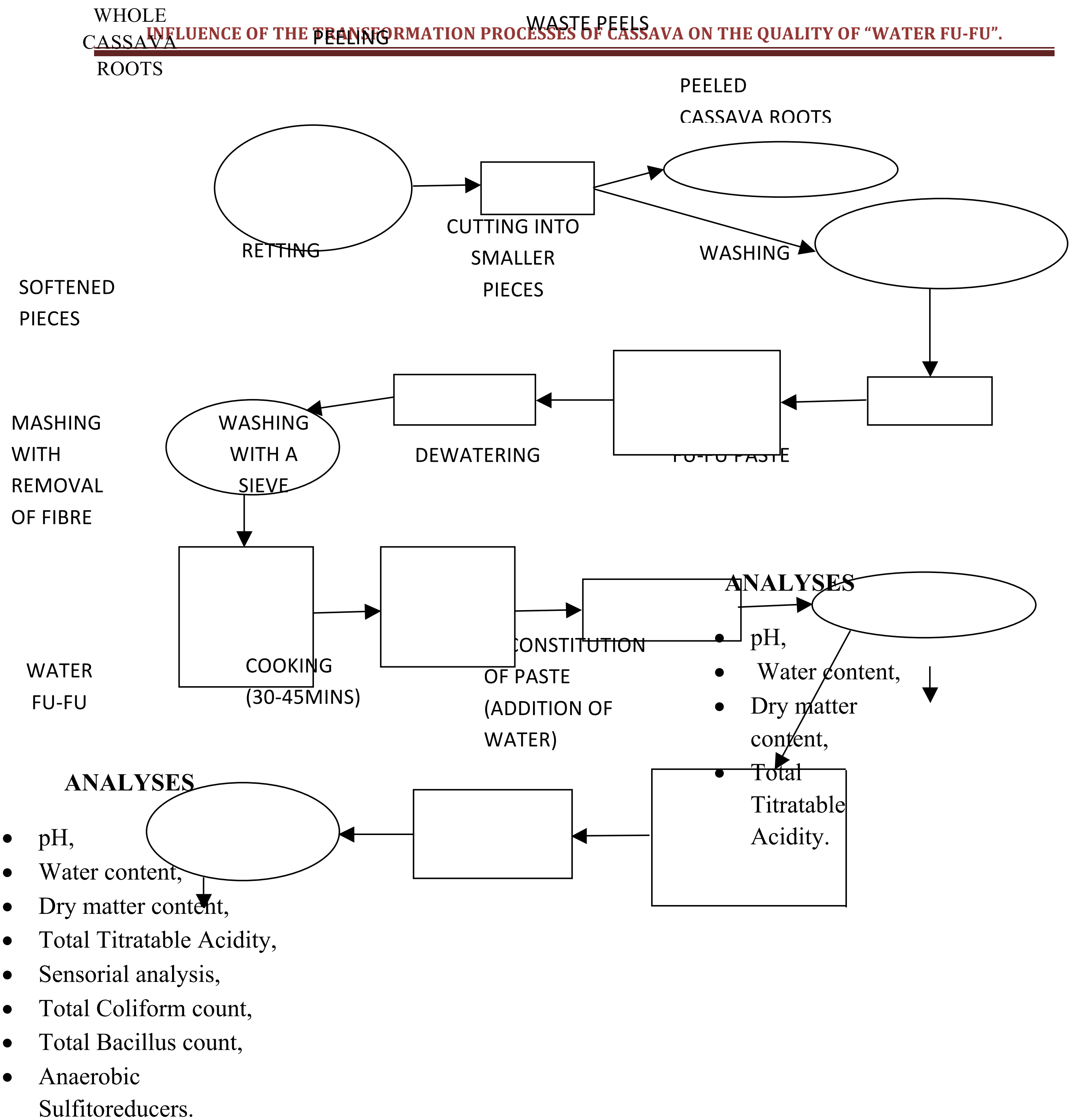


Figure 4: *Protocol for the transformation of cassava roots into water fu-fu.*

1. CHOICE OF THE NUMBER OF RETTING DAYS

The number of days for retting was determined from the questionnaires. The average retting period was calculated and the number of retting days considered for the manipulation derived as the average number of days ± 1 day.

2. DEGREE OF DEWATERING

Three objects with different weights were used for dewatering. At the end of each retting period, the marsh obtained was divided into three equal portions, tied in fiber bags and each portion subjected under the weight of one of the different objects. The bags were left as such until it was observed that no more water was dripping from them. The object with the lowest weight dewatered least and that with the highest weight dewatered most. These three different weights therefore dewatered the three paste portions to three different extents, 1, 2 and 3. The degrees of dewatering were reflected by the water contents of the pastes obtained.

3. DETERMINATION OF AMOUNT OF WATER FOR RECONSTITUTION OF PASTE DURING COOKING (‘DOi’)

The ‘DOi’ in this work refers to the total amount of water added to water fu-fu paste during the reconstitution and cooking processes. Three samples of water fu-fu paste of 500g with different water contents were bought from three different vendors and their water contents evaluated. The pastes were then given to three different cooks who prepared the water fu-fu, each measuring the total amount of water used for the cooking. For better appreciation, each cook prepared one portion of all the three different pastes. The ratio of the dry matter content to volume of water was calculated and the values obtained used during manipulation. A panel was then set up and the different water fu-fu samples evaluated, scoring each quality parameter on ten.

After the sensorial analysis, the two most appreciated products were determined (following the calculation of their Quality Index Means) and their average dry matter content and average DOi values calculated. The ratio obtained was then used as a reference in the determination of the amount of water to be used during the cooking of the different pastes. This was done using the following formula:

$$DOix = \frac{DMx \times DOi1}{DM1}$$

Where:

$DOix$ = DOi of paste sample

$DOi1$ = Average DOi of reference pastes

DMx = Dry matter content of paste sample

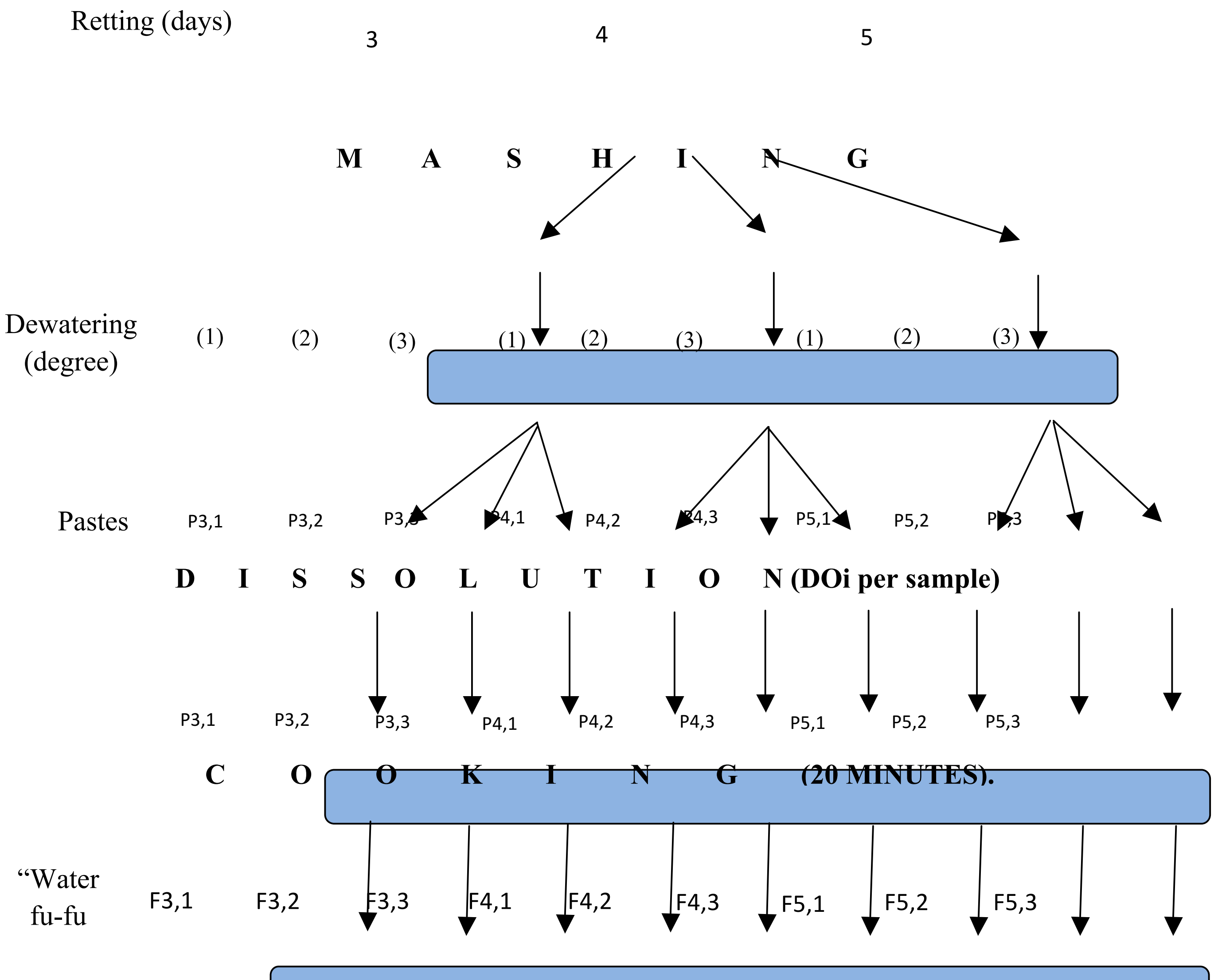
$DM1$ = Average dry matter content of reference pastes

4. DETERMINATION OFTHE CHOICEOF COOKING TIME

The best cooking time was obtained by calculating the average of the various cooking times from the questionnaires. The value obtained was 39.61 (≈ 40) minutes. However, based on trial cooking sessions which were carried out using 500g of paste, the cooking time was reduced to about 20 minutes for 500g of paste sample.

After the obtention of all these parameters, an experimental design was then set up comprising of 1 cassava variety, 3 lengths of retting and 3 degrees of dewatering (**figure 5**)

Cassava roots



NB:

1,2,3:Different degrees of dewatering (1=most dewatered, 2=averagely dewatered, 3=least dew

***Figure 5**: Manipulation protocol showing experimental design*

III.ANALYSIS OF PASTES AND WATER FU-FU

A. PHYSICO-CHEMICAL ANALYSIS

The pH, Water Content, Dry Matter content and Total Titratable Acidity of the pastes and water fu-fu samples were all measured.

1. DETERMINATION OF pH

The pH indicates the degree of acidity of a product. Low acid levels consent a slow rate of deterioration (Amoo and Agunbiade, 2010). To do this, 10g of the sample was mixed with 10ml distilled water and the pH measured using a pH meter (Rex PHS-3C) (Onabolu *et al*., 2002).

2. WATER CONTENT (WC)

Water content is evaluated in order to check the preservability of the fu-fu paste. High moisture content aids microbial growth and reduces the shelf life of food products (Amoo and Agunbiade, 2010). It was measured using a modified version of the method described by AACC, 2000. Two grams of the sample was weighed and dried in an oven (BINDER, 11-08447) at 130^{o}C for 3 hours (instead of 1 hour). The new weight was taken and the water content calculated as follows:

$$\%WC = \frac{W1 - W2}{W1} \times 100$$

Where: W1= initial weight of the sample.

W2= final weight of the sample.

3. DRY MATTER (DM) CONTENT

Determination of the dry matter provides a measure of the amount of the food portion that is required to supply a set amount of nutrients. From the water content evaluation, the dry matter content was calculated as follows:

$$\%DM = 100 - \%WC$$

4. TOTAL TITRATABLE ACIDITY (TTA)

The method described by Owuamanam *et al*., 2010 was used. Five grams of the sample was weighed and dissolved in 100mL distilled water. The solution was left to stand for 30 minutes and filtered using Whatman's filter paper (diameter of 9cm). Twenty five milliliters of the filtrate was then titrated against 0.1M NaOH using phenolphthalein as indicator. The TTA was calculated using the formula

$$TTA = 0.01X$$

Where X = mean titre value.

All the measurements for physico-chemical analyses were carried out in triplicate.

B. SENSORIAL ANALYSIS

Sensorial analysis was used to evaluate the taste, colour, aroma and texture (smoothness, elasticity, softness and gummy nature) of the different water fu-fu samples obtained. The method described by Agatemor, 2009 was adapted to this study with the application of the following criteria:

- The panel was made up of 13untrained regular consumers of 'water fu-fu'.
- The meaning of each attribute (taste, colour, aroma and texture) was clearly explained to the panelists in order to avoid misinterpretation.
- Panelists were not allowed to discuss their scores with one another during the evaluation session.
- Panelists were given one sample at a time to evaluate, clean tap water to rinse their mouths after each tasting and clean mark sheets (table 3) to note their rating, giving a score on 10. This score depended on their degree of appreciation. One sample was bought from the market and used as a commercial control.

In order to get the degree of importance accorded to each quality parameter used for sensorial analysis, the opinion of some consumers was sought, through the use of forms, (**appendix 4**).

***Table 3**: Mark sheet for sensorial analysis*

IDENTIFICATION CODE: ___________

SAMPLE	QUALITY CRITERIA/ SCORE ON 10							
	COLOUR	AROMA	SMOOTHNESS	ELASTICITY	SOFTNESS	GUMMY NATURE	TASTE	OVERALL ACCEPTABILITY
F3,1								
F3,2								
F3,3								
F4,1								
F4,2								
F4,3								
F5,1								
F5,2								
F5,3								
Control								

After this exercise, the scores for the different quality attributes were used to calculate the Ponderated Quality Index Means (PQIM) of the various samples using the formulae below.

$$\%\, Importance\ of\ an\ attribute\ (A)\ = \frac{mean\ score\ for\ that\ attribute}{sum\ of\ mean\ scores\ for\ all\ attributes} \times 100$$

$$PQIM = \frac{\sum(mean\ score\ of\ an\ attribute\ \times A\ of\ the\ same\ attribute)}{10(sum\ of\ \%\ importance\ of\ the\ different\ attributes\ for\ that\ sample)}$$

The samples with the highest PQIM values were considered to be the best samples. Consequently, physico-chemical and microbiological analyses were carried out only on the best three water fu-fu samples.

C. MICROBIOLOGICAL ANALYSIS

The main floral counts taken into consideration were:

- The Total Coliform (TC) counts to evaluate the sanitary conditions of the products.
- The Total Bacillus (TB) counts to evaluate the preservability of the products.
- Anaerobic Sulfitoreducers, (ASR) also to check for preservability.

To do this, serial dilutions of 500g of the test samples were carried out and 1ml of each of the dilutions aseptically inoculated in an appropriate medium for the bacteria to be cultivated. The compositions of the culture media used are given in **appendix 2**. The mode and medium of inoculation depended on the bacteria to be cultivated:

- Pour plate inoculation ("ensemencement en profondeur") in the Mac Conkey medium for the TC count.
- Pour plate inoculation in the Bacillus cereus agar base (without the selective supplement, SR99) for the TB count.
- Inoculation in melted Trypticase Sulfite Neomycine (TSN) agar medium in test tubes for ASR.

After inoculation, all the petri dishes and tubes were incubated at 37^{o}C for 18 to 24 hours after which the number of colonies was counted and expressed as Colony Forming Units per gram (CFU/g) of water fu-fu. Every dilution for each sample was inoculated in triplicate.

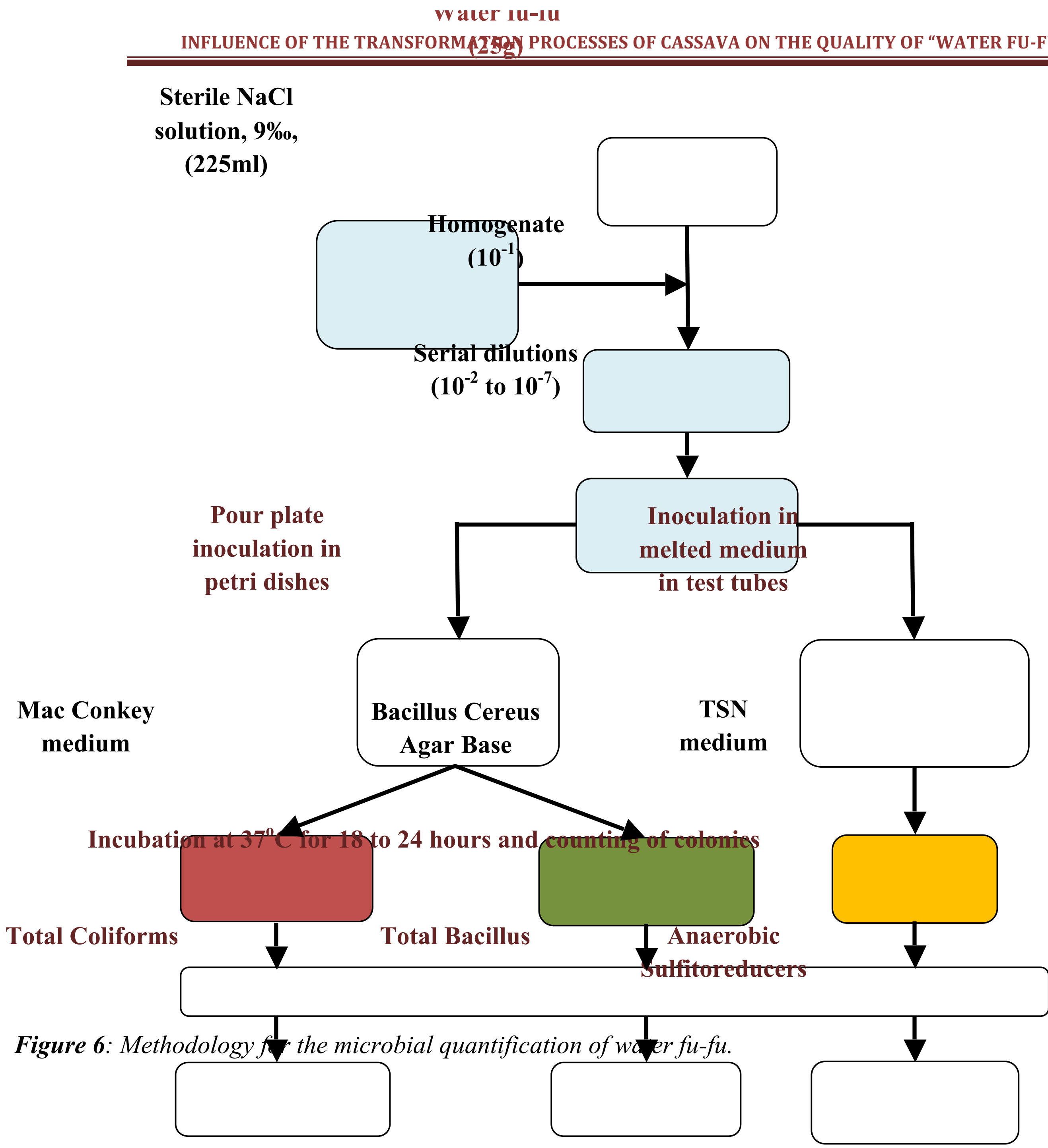


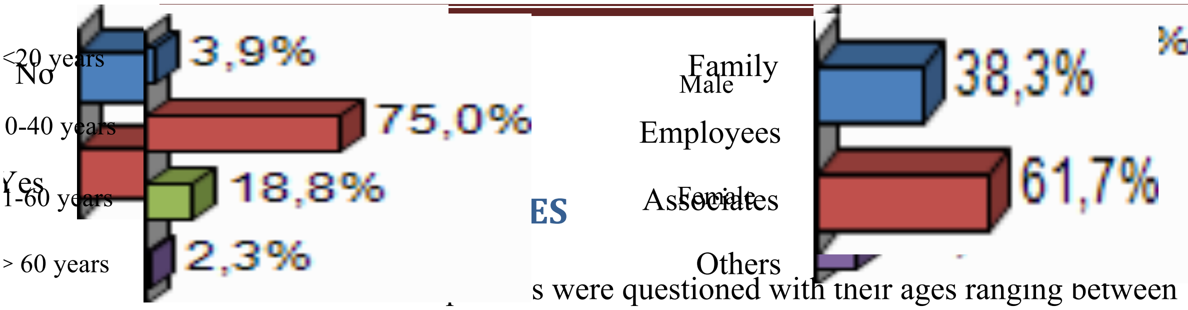
Figure 6: *Methodology for the microbial quantification of water fu-fu.*

D. CORRELATION STUDIES AND PRINCIPAL COMPONENT ANALYSIS

After all of these analyses, a general table showing the results of analyses carried out on water fu-fu was drawn up and used to carry out correlation studies in order to verify how the different parameters studied depended on each other. Furthermore, in order to regroup the final products based on the similarities of the results of the different analyses carried out on them, a principal component analysis was carried out.

E. ANALYSIS OF RESULTS

The results obtained from the different analyses were analysed using the Microsoft Excel 2007 spreadsheet application while correlation studies and Principal Component Analysis were carried out using the STATISTICA 7 of Statsoft.



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s were questioned with their ages ranging between 16 and 65 years.

A. THE PRODUCTION OF WATER FU-FU

Majority of the respondents (75%) were aged between 20 and 40 years and 61.7% of these people interviewed were females. To 61.4% of these people, the production of water fu-fu is an income generating activity. Seventy seven percent of them work with their families, **Figure 7**. Several variations were observed in the process of transformation of cassava into water fu-fu paste. The different transformation pathways are shown in **figure 8** below. Pathway N° 1 was used by 73.33% of these producers.

***Figure** 7: Graphs representing some results from questionnaires*

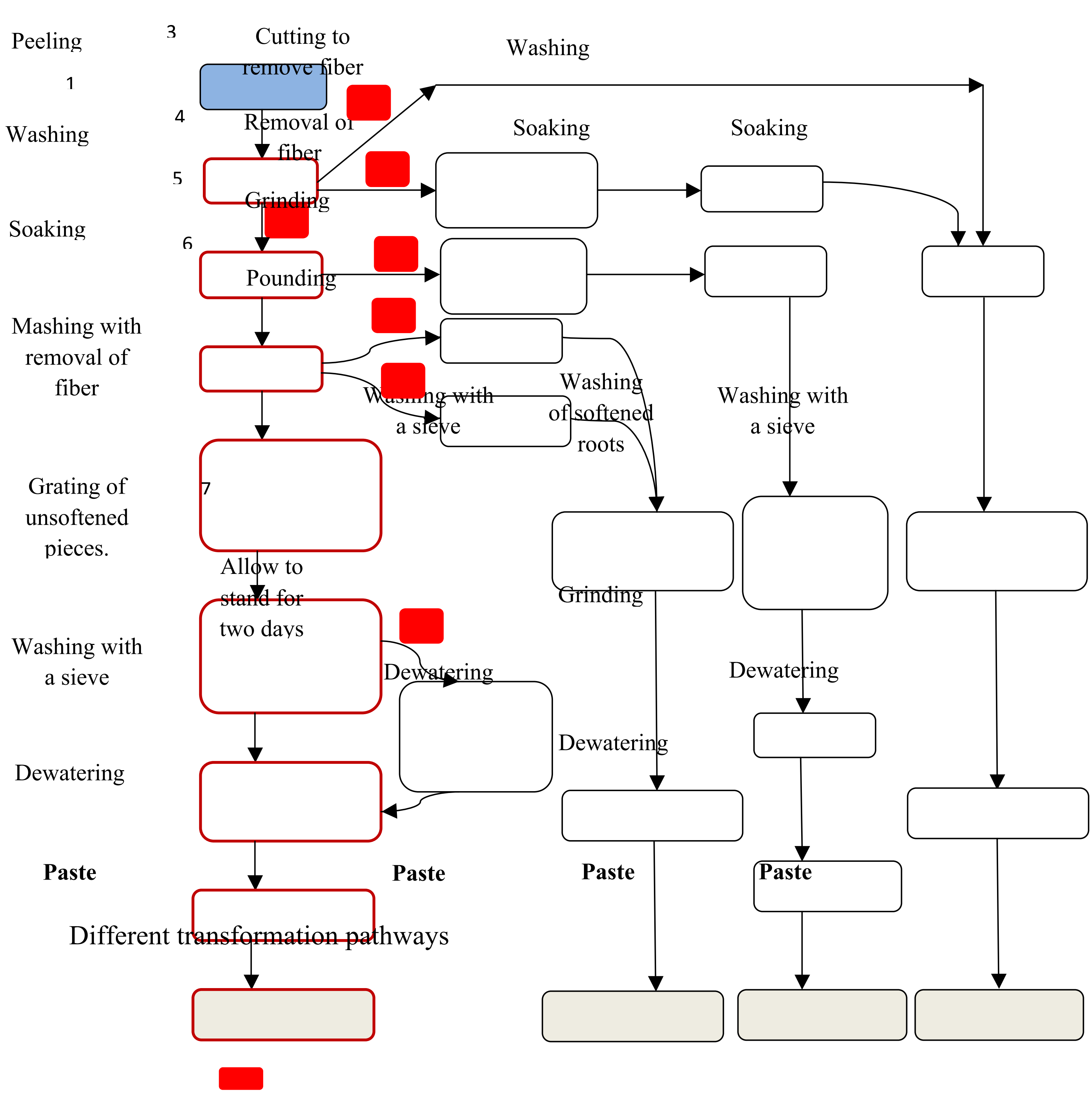


Figure 8: *Different transformation processes used by producers of water fu-fu paste*

The length of retting ranged between 1 day and 7 days with an average retting period of Consequently, the length of retting for our study was varied at 4 days ± 1 day. these people (19.2%) indicated that they add certain substances during retting. mentioned include: unwashed bitter leaves, warm water, corn flour, pawpaw leaves and cassava chips ('cossettes de manioc'), locally known as "koum-koum" in order to shorten the length of time taken for the cassava roots to get soft. Some add a pinch of salt (NaCl) to prevent smelling as well as the growth of maggots in the paste.

Different lengths of squeezing were indicated but very little can be said about this since the degree of dewatering depends more on the force exerted on the paste. As concerns preservation, different preservation methods were obtained including:

- Pound in a big plastic bag and tie well, then place in a plastic bucket and cover tightly.
- Tie in small plastic bags and keep under cold water in a bath.
- Pound in plastic bags and tie in a bigger, stronger bag.
- Refrigerate in plastic bags.

As for cooking time, the majority (57.8%) of people cooked between 40 and 49 minutes. The average cooking time was 39.61 (≈ 40) minutes with 92.2% of these people cooking their water fu-fu for home consumption.

Majority of the producers were only able to preserve their pastes for less than 20 days, **figure 9**. This calls for intervention as far as the shelf-life of water fu-fu paste is concerned.

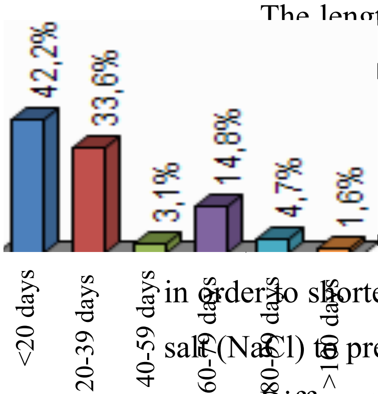


Figure 9: *Graph showing different durations of preservation of water fu-fu paste from questionnaires*

These producers faced a number of problems which ranged from uneven softening of the cassava tubers during retting to difficult storage conditions, lack of cassava during certain periods of the year especially the dry season (probably due to the dryness of the soil which makes digging difficult) and transportation of the tubers from farm to market due to bad roads.

B. THE CONSUMPTION OF WATER FU-FU

Almost all (91.4%) of these people consume their water fu-fu at home. During consumption and depending on the preferences of the different individuals, different sensorial characteristics were appreciated differently as shown on **table 4** below. More people preferred water fu-fu with a less acidic taste, a whitish colour and a soft, smooth and elastic texture.

***Table 4**: Sensorial preferences of water fu-fu consumers*

Parameter	Dislike extremely	Dislike	Average	Like	Like extremely	Total
Less acidic taste	14.06%	21.87%	34.38%	25%	4.69%	100%
Acidic taste	28.91%	23.44%	25.78%	16.41%	5.47%	100%
Whitish colour	4.69%	17.97%	22.66%	18.75%	35.94%	100%
Creamy colour	14.06%	15.63%	29.69%	30.47%	10.16%	100%
Fermented (acidic) aroma	26.56%	28.91%	28.13%	11.72%	4.69%	100%
No aroma	8.59%	32.03%	24.22%	18.75%	16.41%	100%
Gummy texture	53.91%	25.78%	17.97%	1.56%	0.78%	100%
Hard texture	42.19%	32.81%	16.41%	7.03%	1.56%	100%
Soft texture	8.59%	14.06%	40.63%	15.63%	21.09%	100%
Smooth texture	0%	0.78%	3.91%	23.44%	71.88%	100%
Elastic texture	7.03%	11.72%	27.34%	29.69%	24.22%	100%

Some consumers indicated that they experience certain problems after consumption which ranged from stomach disorders (stomach ache, constipation, indigestion, diarrhea and gastritis) to heart burn, hard stool, yeast cells, typhoid, vomiting, dizziness and a feeling of drunkenness.

II. PRELIMINARY ANALYSES FOR THE PRODUCTION OF WATER FU-FU

A. OBTENTION OF DOi

Three samples of fermented cassava pastes (a, b and c) of 500g each and different water contents were given to 3 cooks recruited for the experiment. The cooks were asked to measure the total amount of water used to prepare each water fu-fu sample. The results of this experiment are shown in **table 5** below. The average length of time used to prepare each of the samples was 20 minutes.

Table 5*: Amount of water added by cooks to the pastes with different water contents*

Paste Samples	WC (%)	DM (%)	DIFFERENT COOKS			Average DOi(mL)
			A (mL)	B(mL)	C(mL)	
I	24.5	75.5	445	425	390	420
II	21.5	78.5	450	490	405	448.3
III	22	78	445	355	340	380

After the pastes had been cooked, a panel did sensorial analyses of the different fu-fu samples obtained based on the scheme presented on table 3. Each parameter was scored on 10 and the mark given depended on the panelist's level of appreciation of the product. The scores on **table 6** are the averages of the scores given by the different panelists for each of the quality parameters.

Table 6*: Average scores obtained from preliminary sensorial analysis*

SAMPLE	QUALITY CRITERIA/ SCORE ON 10							
	COLOUR	AROMA	SMOOTHNESS	ELASTICITY	SOFTNESS	GUMMY NATURE	TASTE	QUALITY INDEX
Ia	7.25	9	9	7.25	8.5	6.5	9.25	8.11
Ib	8.25	7.5	4.5	6.75	7.5	7.75	7.5	7.11
Ic	7.75	8.5	5.75	5.25	5.75	7	8.5	6.93
IIa	1.75	9	4.5	7.25	4.75	2.75	2.5	4.64
IIb	5.75	4.75	6.25	3.5	5	1.75	1.25	4.04
IIc	4	2.25	4.75	3.25	5.75	5.75	2.75	4.07
IIIa	9.75	9.5	8.5	8.5	9.25	8.5	8.75	8.96
IIIb	10	10	9.5	7.75	10	10	9.75	9.57
IIIc	8.25	6.75	8.25	6.75	5.75	8.75	9.75	7.75

After the sensorial analyses, the Quality Index Means were calculated. The values obtained revealed that samples I and III were the most appreciated. Calculation of the average dry matter contents and DOi values for samples I and III gave a ratio of average dry matter content to average DOi value of 76.75% to 400mL for 500g of paste. This ratio was used to calculate the DOi for the different paste samples during subsequent manipulations.

B. CONSUMER EXPECTATIONS

In order to assess the degree of importance accorded to the different quality attributes of water fu-fu by its consumers, a questionnaire was presented to regular consumers. They were asked to grade from 1 to 10 the level of importance they attributed to the listed sensorial parameters of water fu-fu. Following the evaluation of consumer expectations, the percentage importance accorded to the different quality attributes in decreasing order of importance were as follows: taste (17.26%), smoothness (16.04%), colour (15.2%), softness (13.88%), aroma (13.51%), gummy nature (12.29%) and elasticity (11.82%), (**Appendix6**).

III. ANALYSES OF PASTES AND WATER FU-FU

A. ANALYSIS OF PASTES

All the results of paste analyses are shown on **table 7** below.

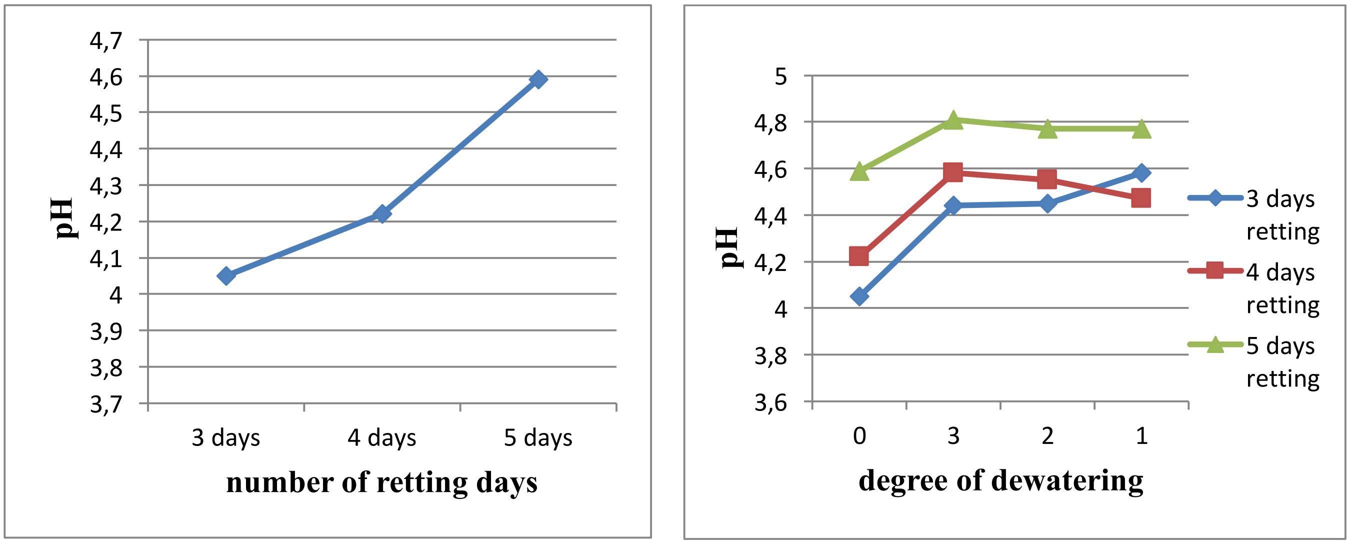
1. pH

The pH values were measured before and after dewatering. Overall, the pH value was lowest on the third day of retting (4.05), followed by a slow rise through the fourth and fifth days (4.22 and 4.59 respectively), **figure 10a**. For all the paste samples, the values increased after dewatering, that is, the pastes became less acidic. It was also observed that for three days of retting, the acidity continuously decreased with increase in the degree of dewatering. However, after retting for four and five days, the acidity instead increased with increase in the degree of dewatering, **figure 10b.**

2. WATER CONTENT AND DRY MATTER CONTENT

From a general point of view, the water content of the pastes increased with increase in the number of retting days. Also, as the degree of dewatering at the end of each retting period increased, the water content decreased proportionately.

On the other hand, the variation of the dry matter contents was inversely proportional to the water contents.



(a) **(b)**

Figure 10: *Graphs showing the variation of pH* ***(a)*** *before dewatering and* ***(b)*** *at the different degrees of dewatering*

Legend

0: before dewatering; 3: least dewatered; 2: averagely dewatered; 1: most dewatered.

3. TOTAL TITRATABLE ACIDITY (TTA)

The TTA of all the pastes after all the different lengths of retting was the same.

The commercial control used had a much lower pH value, a higher TTA value, higher water content and consequently a lower dry matter content in comparison to the different pastes obtained.

***Table** 7: Results of physico-chemical analyses of pastes samples*

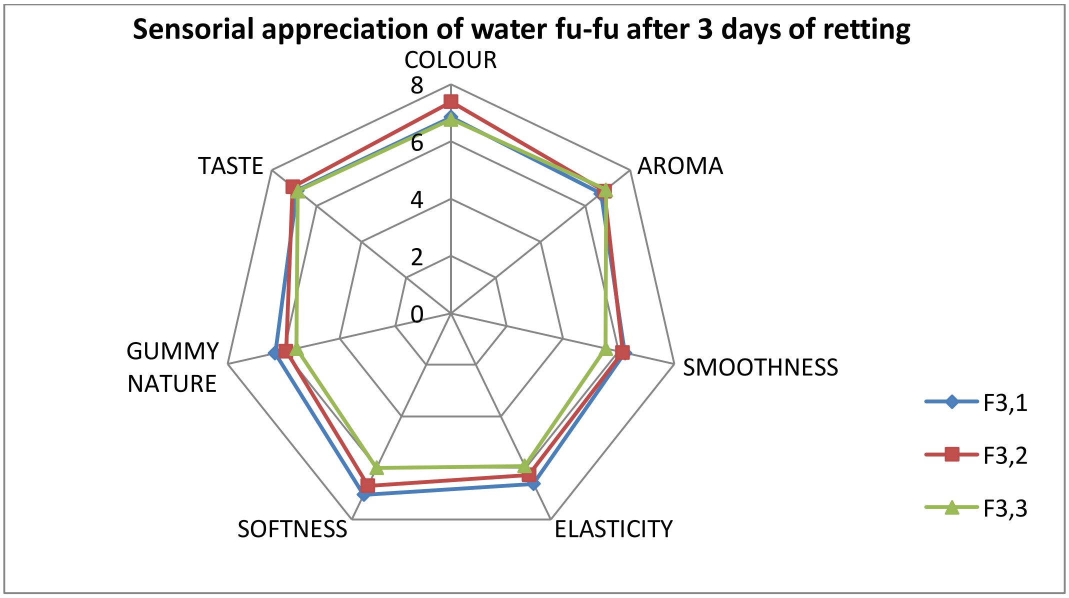
Analyses	PASTE SAMPLE (500g)									
	P3,1	**P3,2**	**P3,3**	**P4,1**	**P4,2**	**P4,3**	**P5,1**	**P5,2**	**P5,3**	**commercial control**
pH before squeezing	4.05			4.22			4.59			-
pH after squeezing	4.58	4.45	4.44	4.47	4.55	4.58	4.74	4.77	4.81	3.72
%WC	5.37	10.24	11.22	6.73	10.1	11.54	11.54	12.98	14.42	29.8
%DM	94.63	89.76	88.78	93.27	89.9	88.46	88.46	87.02	85.58	70.2
%TTA	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.53
DOi (mL)	493.2	467.8	462.7	486.1	468.5	461	461	453.5	446	365.9

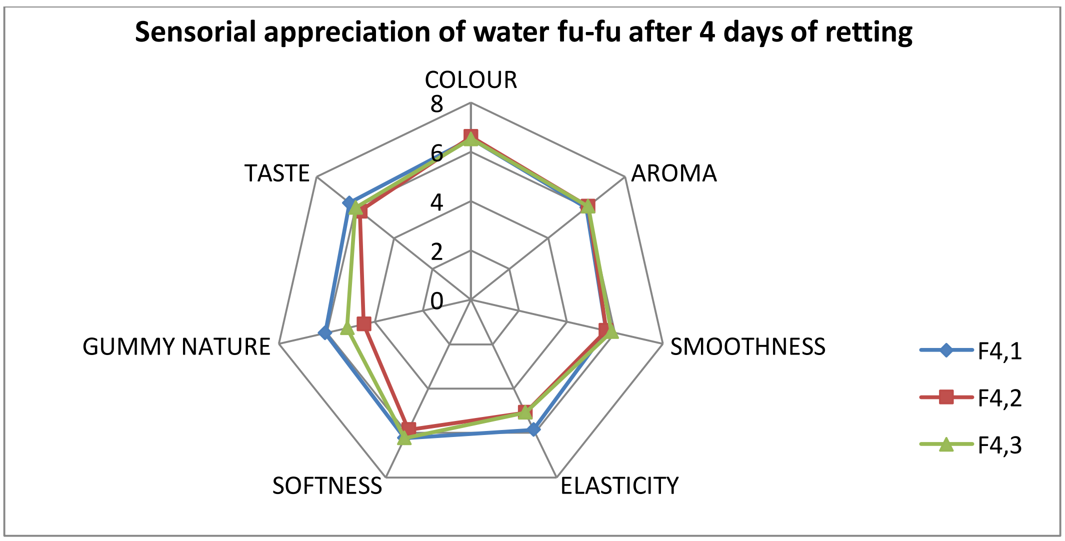
B. ANALYSES OF WATER FU-FU

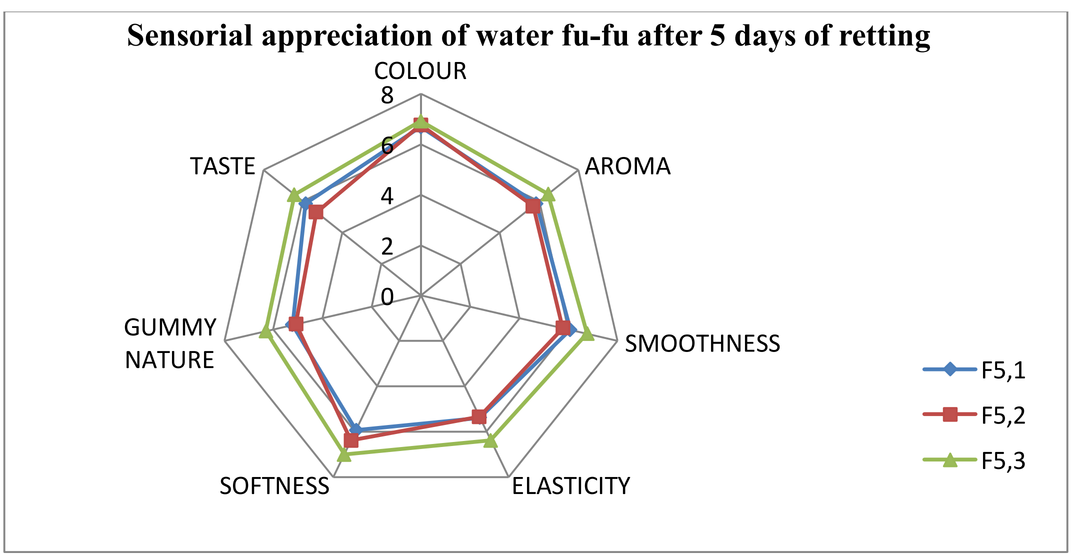
1. SENSORIAL ANALYSES

The various paste samples, P3,1 to P5,3 were used to prepare samples of water fu-fu, F3,1 to F5,3. For each of the water fu-fu samples, a sensorial analysis was carried out. The average scores per attribute for each sample determined from the results of the sensorial analyses are summarised on **appendix 7**. These analyses revealed the following: All the samples were globally appreciated by the panelists. Samples F3,1; F3,2 and F3,3 were the most appreciated samples in terms of Aroma and Taste. Samples F3,1; F3,2 and F5,3 were the most appreciated samples in terms of Colour, Smoothness, Elasticity and Softness.

The sensorial acceptability of the various products obtained during this work as well as the consumer preferences are shown on **figure11** below.


Sensorial appreciation of water fu-fu after 3 days of retting
COLOUR
AROMA
SMOOTHNESS
ELASTICITY
SOFTNESS
GUMMY NATURE
TASTE
0
2
4
6
8
F3,1
F3,2
F3,3


Sensorial appreciation of water fu-fu after 4 days of retting
COLOUR
AROMA
SMOOTHNESS
ELASTICITY
SOFTNESS
GUMMY NATURE
TASTE
0
2
4
6
8
F4,1
F4,2
F4,3


Sensorial appreciation of water fu-fu after 5 days of retting
COLOUR
AROMA
SMOOTHNESS
ELASTICITY
SOFTNESS
GUMMY NATURE
TASTE
0
2
4
6
8
F5,1
F5,2
F5,3

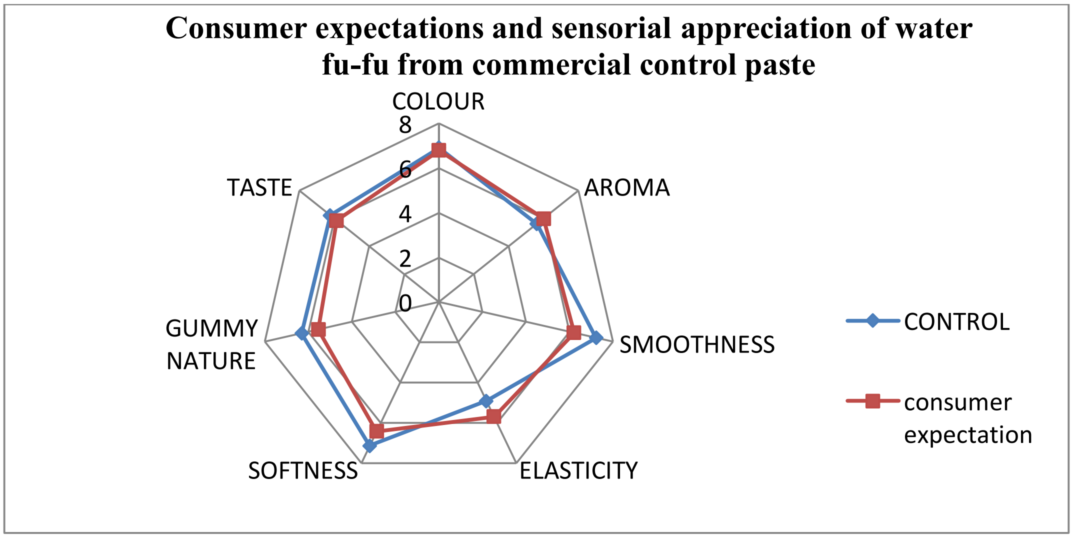


Figure 11: *Sensorial acceptability of different water fu-fu samples and consumer preferences.*

At the end of the sensorial analyses, samples F4,2 and F5,2 were the least appreciated. On the other hand, samples F3,1; F3,2 and F5,3 had the highest Quality Index Means, indicating that they were the most appreciated water fu-fu samples. Consequently, physico-chemical and microbiological analyses were carried out only on these samples.

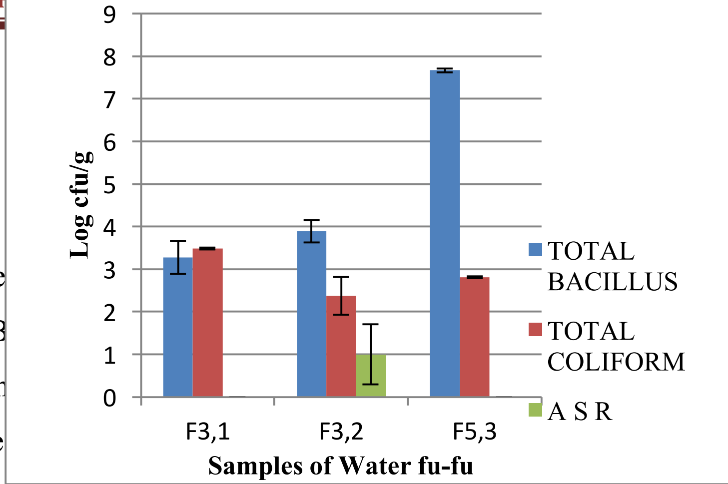
2. PHYSICO-CHEMICAL ANALYSES

After cooking, the pH values of the fu-fu samples analysed all dropped as compared to their values before cooking. However, the TTA values remained the same. On the other hand, their water contents and dry matter contents increased and decreased respectively. The values obtained are shown on **table 8** below.

Table 8: *Results of the physico-chemical analyses of water fu-fu samples*

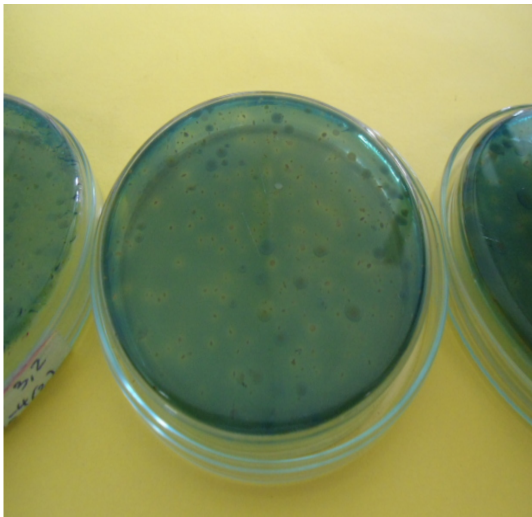
SAMPLE	ANALYSES			
	pH	%WC	%DM	TTA ($\times10^{-3}$)
F3,1	4.46	22.25	77.75	1
F3,2	4.36	37.25	62.75	1
F5,3	4.74	33	67	1

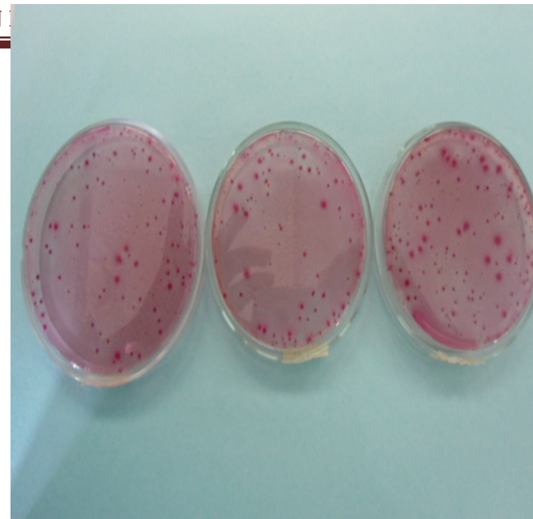
***Figure 12**: Graph representing results of microbiological analyses*



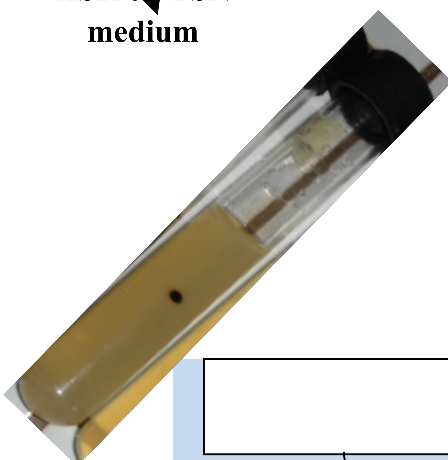
3.

The … was no significant difference in Total B… its part was highly charged. As concern… as observed in the three samples analyse… c Sulfitoreducers. The results of these analyses are shown on **figure 12** below.





ASR on TSN medium



cture 5: *Different microbial colonies grov … (By Njang)*

C. CORRELATION BETWEEN THE DIFFERENT PARAMETERS ANALYSED ON WATER FU-FU

The results of the correlation studies are shown on **table 9** below. Correlations were said to be significant at $p < 0.05$ and are indicated in red ink on the table. These significant correlations were either positive or negative and revealed the following:

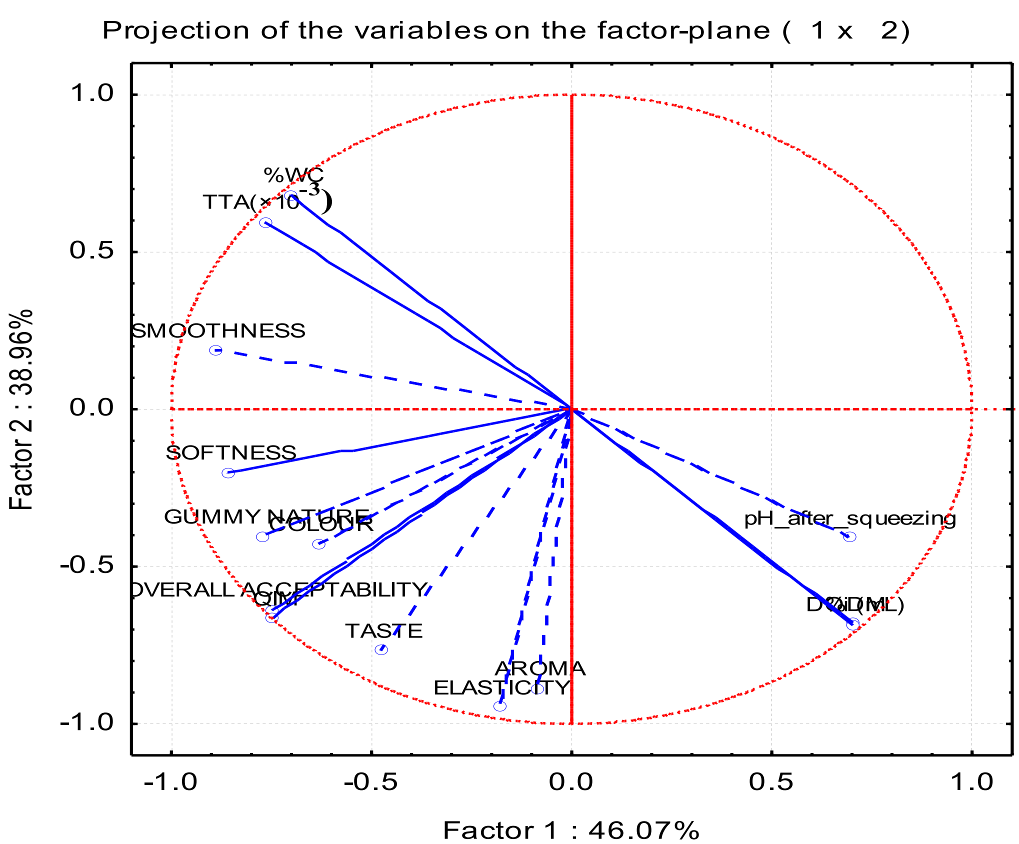
As concerns the physico-chemical analyses, the pH after squeezing correlated negatively with %WC and TTA but positively with %DM and DOi. There was no significant correlation between pH and any of the sensorial parameters. %WC, TTA and smoothness all correlated positively amongst themselves but negatively with DOi. None of these physico-chemical parameters significantly correlated with the QIM.

As concerns the sensorial analyses, no negative correlations were observed between the different sensorial parameters. Only smoothness had a significant correlation with the physico-chemical parameters analysed. On one hand, there were significant correlations between aroma, elasticity, taste, softness, smoothness and gummy nature while on the other hand, colour did not correlate with any other parameter apart from overall acceptability and QIM. The overall quality of the water fu-fu directly correlated to: Taste (86.38%), Gummy nature (86.16%), Softness (77.92%), Elasticity (77.12%), Colour (73.48%), and Aroma (64.56%).

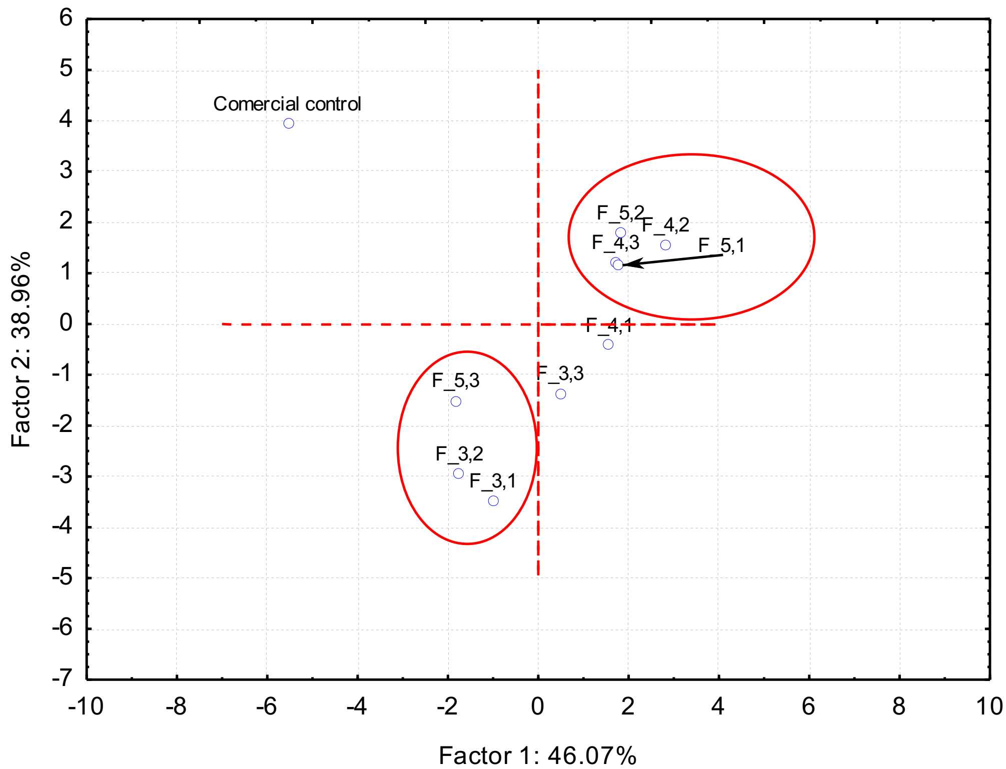
Table 9: *Correlation between the different parameters analysed on water fu-fu*

VARIABLE	CORRELATION ANALYSES													
	pH after squeezing	%WC	%DM	TTA ($x10^{-3}$)	DOi (mL)	Colour	Aroma	Smoothness	Elasticity	Softness	Gummy nature	Taste	Overall acceptability	QIM
pH after squeezing	1.00	-.7223	.7223	-.9011	.7220	-.1985	.1991	-.4970	.3527	-.3693	-.3521	-.2299	-.2620	-.2363
%WC		1.00	-1.00	.9156	-1.00	.1985	-.4813	.7461	-.5206	.4222	.2185	-.1832	.0949	.0688
%DM			1.00	-.9156	1.00	-.1987	.4813	-.7461	.5206	-.4222	-.2185	.1832	-.0949	-.0688
TTA ($x10^{-3}$)				1.00	-.9154	.1707	-.4468	.7353	-.4426	.5047	.3656	-.0251	.2018	.1751
DOi (mL)					1.00	-.1985	.4816	-.7460	.5209	-.4219	-.2184	.1836	-.0945	-.0684
Colour						1.00	.4736	.4580	.4730	.5669	.4513	.5802	.7585	.7348
Aroma							1.00	-.1823	.7818	.1064	.2777	.8480	.6707	.6456
Smoothness								1.00	.0344	.8257	.6410	.1687	.5473	.5492
Elasticity									1.00	.4049	.6025	.7365	.7176	.7712
Softness										1.00	.8193	.4026	.7619	.7792
Gummy nature											1.00	.6477	.7802	.8616
Taste												1.00	.8478	.8638
Overall acceptability													1.00	.9739
QIM														1.00

Following the correlation studies, a principal component analysis was performed in order to regroup the final products based on the similarities of the results of the different analyses carried out on them. The results are shown on **figure 13** below. The results showed that samples F3,1; F3,2 and F5,3 (which were the most appreciated fu-fu samples) fell within the same plane, having similar results with respect to their softness, gummy nature, taste, elasticity, aroma and overall acceptability. On the other hand, samples F4,2; F4,3; F5,1 and F5,2 which formed the second group were not specifically affected by a particular variable. The commercial control on its part was clearly different from the experimental water fu-fu samples while samples F3,3 and F4,1 also fell in yet another plane of their own with similar values of pH after squeezing and DOi.



(a)



(b)

Figure 13 (a) and (b): *Results of Principal Component Analysis*

DISCUSSION

Following the results of the questionnaires, the age range of 20 to 40 years for the respondents indicates the involvement of an active population. The involvement of a larger proportion of women in the sector confirms the observation of Tricoche *et al*., 2008 who reported that roots and tubers are mainly cultivated by women with the aim of getting supplementary revenue. Also, the fact that a larger percentage of these people work with their families indicates that the production of water fu-fu paste has not yet been industrialized, despite the growing demand for it.

Following the physico-chemical analyses, the low pH values obtained just after retting, before dewatering has been reported to be due to the presence of organic acids produced by Lactic Acid Bacteria (LAB), which are dominant during retting. These organic acids, which acidify the medium, include lactate, acetate and butyrate from the degradation of fructose, saccharose and glucose respectively (Brauman *et al*., 1995; Brauman *et al*., 1996; Kostinek *et al*., 2008). The drop in pH to the third day of retting was probably due to the accumulation of organic acids produced by LAB. However, the slow rise through the fourth and fifth days could be attributed to the volatility of part of the short chained acids produced as they diffused into the retting water. It could also be due to the metabolisation of the acid molecules by bacteria, probably due to shortage of nutrients. These results are generally consistent with results of other cassava fermentations as reported by Brauman *et al*., 1995, Kimaryo *et al*., 2000 (on 'agbelima' in Ghana) and Tetchi, 2012 (on 'attieke' in Ivory Coast). The slight increase in the pH of all the pastes obtained after the different degrees of dewatering can be justified following the report by Obilie *et al*., in 2004 that dewatering leads to the loss of organic acids in the pressed liquor and consequently a rise in pH.

The decrease in acidity with increase in degree of dewatering after three days of retting is probably because the starch granules are less hydrolysed and as such less organic acids have penetrated into them. Consequently, as the degree of dewatering increases, more of these organic acids are eliminated, given that the less hydrolysed starch granules do not have the tendency of retaining much water. On the other hand, the starch granules at four and five days of retting are more hydrolysed and so have incorporated more organic acids in solution. Being more hydrolysed, these granules (having a larger contact surface) will establish stronger bonds with the acid molecules than with water and consequently can retain their acidity during dewatering. This could account for the fact that after these lengths of retting, the acidity of the pastes increases with increase in the degree of dewatering. On the other hand, the ability of starch granules to retain more water as they get more hydrolysed could also account for the overall increase in the water content of the pastes as the length of retting increased. This increase in water content is translated into a decrease in dry matter content since these two are inversely proportional. Regarding the drop in pH after cooking, probably the organic acids, being bonded to the amylose and amylopectin molecules did not evaporate during cooking. The absorption of water by the starch granules therefore increased the concentration of the acids, resulting in a drop in pH. From the physico-chemical analyses, it can be observed that as retting proceeds, there is a drop in the acidity of the medium which confers on the water fu-fu its characteristic taste and aroma. Nonetheless, prolonged retting will end up with a slightly less acidic product with loss of dry matter.

Following the sensorial analyses of the water fu-fu samples, the fact that samples F3,1; F3,2 and F3,3 were the most appreciated in terms of aroma and taste takes us back to the pH value at three days of retting which was the least. Brauman *et al*., 1995; Obilie *et al*., 2004 and Djoulde, 2005 report that the acidification which cassava dough undergoes during retting, accompanied by the production of acetoine, acetaldehyde and peptides are responsible for the sour taste and typical flavour of the product. Kimaryo *et al*., 2000 on their part report that *Lactobacillus plantarum* in particular has the ability to produce aromatic compounds in a population dominated by LAB, which thereby impart a pleasant aroma to the final product. Sample F5,3 was most appreciated for its smoothness and gummy nature, probably due to the longer retting time which led to more hydrolysis of starch granules and consequently, better disintegration of fiber. Going by the average scores obtained for the colour of the different water fu-fu samples, there was no significant difference between them. This could be attributed to the fact that the same species of cassava was used, harvested from the same farm. In addition, the work done by Ampe *et al*., 1994 showed that fu-fu prepared with roots peeled after retting is light brown whereas roots that are peeled before retting give white fu-fu. We can also say that the length of retting and degree of dewatering do not greatly influence the colour of water fu-fu. As concerns the softness of water fu-fu, it depends more on the volume of water added during cooking and varies based on consumer preferences. A consumer who prefers hard water fu-fu will add in less water while one who prefers soft water fu-fu will add in more water. From the sensorial analyses, it is observed that consumers preferred water fu-fu which was either less retted and more dewatered or more retted and less dewatered.

As concerns the microbiological analyses of the most appreciated water fu-fu samples, less Bacilli in F3,1 and F3,2 than in F5,3 is likely because F3,1 and F3,2 were more acidic than F5,3. The higher acidity likely limited the growth of bacilli. This could also be attributed to the report by Tetchi, 2012 that LAB have an antimicrobial property whereby strains of *Lactococcus lactis* (in case they were present), produce bacteriocins and hydrogen peroxide which could have an inhibitory effect on the growth of bacilli. Also, the fact that F3,1 (which was more dewatered than F3,2) was less charged with Bacilli than F3,2 indicates that dewatering probably eliminated some of the bacterial cells. The statistically insignificant difference in Total Coliform count could be an indication of contamination either from the water and/or material used for cooking or from the environment. It could also indicate insufficient thermal treatment during cooking. The fact that ASR were absent in F3,1 and present only in F3,2 could be an indication of contamination, given that the water fu-fu medium being humid will more likely have ASR in the vegetative form rather than in the form of spores. The effect of temperature during cooking will rather destroy these vegetative cells, reason why clostridium cells are virtually absent. From the microbiological analyses, we can observe that dewatering leads to the loss of some bacterial cells. Due to the high amounts of bacilli (because of their facultative aero-anaerobic nature), we can say that the liquefaction of water fu-fu after a period of preservation could possibly be due to the presence of bacilli.

As concerns the correlation studies, the negative correlation between %WC and pH indicates that pH increases as %WC decreases. This suggests that there is loss of acidity during dewatering. The positive correlation between %WC and smoothness suggests that during the preservation of a less dewatered paste, there could be continuous hydrolysis of the starch granules which could be responsible for smoothness of the water fu-fu. In line with this, the negative correlation between smoothness and DOi suggests that the smoothness of water fu-fu is negatively influenced by the amount of water added to the paste during reconstitution and cooking. Moreover, the addition of more water during cooking increases the swelling capacity of the starch and more addition will lead to a gummy water fu-fu.

The fact that no negative correlations were observed between the sensorial parameters indicates that variation in one of these parameters has a direct influence on the others. Colour, which correlated only with the QIM indicates that consumers are usually first attracted to the physical appearance of food before looking out for the other sensorial parameters. Aroma on its part is correlated with elasticity, possibly because the aroma of water fu-fu is released during the chewing process. This suggests that a more elastic water fu-fu will be able to retain more of its aroma during cooking and progressively release it during chewing. The same reason could be attributed to the correlation between aroma, elasticity and taste. Regarding the results of the principal component analysis, taste, gummy nature, softness, elasticity, colour and aroma (factors which directly influenced the quality of water fu-fu as revealed by the correlation analysis) were projected in the same factor plane. This result indicates that in our experiment, the afore-mentioned parameters contribute in the same way to the organoleptic quality of water fu-fu. It further showed that the results of these parameters for samples F3,1; F3,2 and F5,3 were similar by projecting them into the same plane. These samples happen to have been the most appreciated water fu-fu samples following the calculation of the PQIM, thereby confirming the results obtained earlier on.

CONCLUSION

The main aim of this research work was to assess the impact of the critical unitary operations during the production of water fu-fu on its quality. The following conclusions can be drawn:

- Different transformation processes are used by water fu-fu producers who are mainly women. A flow sheet of these different processes has been elaborated from which the most used process constituted of 9 main unitary operations: harvesting, peeling, washing, soaking, mashing with removal of fiber, washing with a sieve, dewatering, reconstitution of paste and cooking.

- Based on the analyses carried out, the quality parameters which are most appreciated by consumers of water fu-fu (less acidic taste, smooth, elastic and soft texture and whitish colour), classified in order of consumer preference were influenced by the pH, length of retting and degree of dewatering.

- The water fu-fu samples with the best qualities (based on PQIM) were obtained from pastes which were as follows:

  - Retted for a shorter time (3 days) and more dewatered.
  - Retted for a longer time (5 days) and less dewatered.

  Microbiological analysis carried out on these best water fu-fu samples showed that only one sample revealed the presence of Anaerobic Sulfitoreducers, which was attributed to contamination, given that the cells were more likely in their vegetative form. Furthermore, the Total Coliform counts were not different between the samples with the best qualities. Only the sample retted for five days had significant Total Bacilli, allowing the conclusion whereby water fu-fu obtained from a transformation process including retting for 3 days with more dewatering had the best quality. These samples showed increase in pH after dewatering indicating a correlation with consumer preference of less acidic water fu-fu.

PERSPECTIVES

Several aspects of research need to be carried out in order to extend the present study and be able to standardise the production of water fu-fu in Cameroon. It is proposed that in the near future, the following should be carried out:

- Study the effect of retting at a larger scale, from 1 to 7 days in order to get the shortest retting time which yields good quality water fu-fu.
- Study the effect of temperature on retting time due to varying seasons in Cameroon, coupled with the global climate change.
- Measure other parameters such as the nutritional quality, rheological parameters and extend the number of microbial flora studied.
- Evaluate the effect of retting time on the quality of lyophilised water fu-fu paste and on its performances during water fu-fu preparation.

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APPENDIX 1:

SURVEY QUESTIONNAIRE

This questionnaire is meant to serve as a tool in the realisation of a piece of research work entitled **"INFLUENCE OF THE TRANSFORMATION PROCESSES OF CASSAVA ON THE QUALITY OF 'WATER FU-FU'"**. We will be grateful for your consent to answer precisely the following questions. This questionnaire does not carry any information that will identify you. All information collected will be kept confidential and used only for the purpose of research. If you have any question at any time relative to the use of this questionnaire information you provided, please call Prof Essia Ngang at 77 94 28 04

I. PERSONAL IDENTIFICATION

Sex: *Male* ☐ *Female* ☐ **Age:** ____________________

Marital status: *Single* ☐ *Married* ☐ *Divorced* ☐ *Widow(er)* ☐

Region of origin: ______________, **Village of origin:** ____________________

Profession: ____

II. WITH RESPECT TO THE PRODUCTION OF 'WATER FU-FU'.

1) **Is the production of 'water fu-fu' paste an income generating activity for you?**

Yes ☐ *No* ☐

If yes, for how many years have you been in this activity?______________

2) **With whom do you work?**

Family ☐ *Employees* ☐ *Associates* ☐ *Others (Precise)* ______________

3) **Briefly list the stages you follow in the production of 'water fu-fu'. (Go from first stage to last stage).**

____

____

____

____

____

4) **For how many days do you soak your cassava?** ______________________

Which kind of container do you use? ______________________

Where do you get the water used for soaking? ____

Do you add in anything when soaking? ____

If yes, what and why?____

____

_____

5) **What do you use for squeezing? ____**

For how long do you squeeze your paste? ____

6) **How do you recognize good paste?**

____

____

7) **If you obtain paste from the market, do you cook directly? That is without squeezing again.**

____

8) **How do you preserve your paste before cooking day?**

____

____

9) **For how long can you keep your paste before it gets bad? ______________________________**

10) **Do you cook 'water fu-fu' for commercial purposes or for home consumption?**

____

For how many minutes do you cook your 'water fu-fu'? _______________________________

11) **Which problems do you face during the transformation process?**

____

____

____

____

____

III. <u>WITH RESPECT TO THE CONSUMPTION OF 'WATER FU-FU'.</u>

1) **How many times do you eat 'water fu-fu' in a week? ____________________**

2) **With what do you eat your 'water fu-fu'? ______________________________**

3) **Do you eat in a restaurant or at home? ________________________________**

4) **During consumption, what are those characteristics you look for?**

(Tick **1** for dislike extremely, **2** for dislike, **3** average, **4** for like, **5** for like extremely).

Characteristic of water fu-fu	Parameter	Degree of appreciation				
Taste	Sweet	1	2	3	4	5
	Acidic	1	2	3	4	5
Colour	Whitish	1	2	3	4	5
	Creamy	1	2	3	4	5
Aroma	Fermented (acidic)	1	2	3	4	5
	No aroma	1	2	3	4	5
Texture	Gummy	1	2	3	4	5
	Hard	1	2	3	4	5
	Soft	1	2	3	4	5
	Smooth	1	2	3	4	5
	Elastic	1	2	3	4	5

5) **Do you often face any problem(s) after consuming water fu-fu? _______**

If yes, which?

____

____

THANK YOU FOR YOUR KIND CO-OPERATION

APPENDIX 2

COMPOSITION OF CULTURE MEDIA USED (formulae in g/l)

BACILLUS CEREUS AGAR BASE:

Peptone	1
Mannitol	10
Sodium chloride	2
Magnesium sulphate	0.1
Di-Sodium hydrogen phosphate	2.5
Potassium dihydrogen phosphate	0.25
Sodium pyruvate	10
Bromothymol blue	0.12
Agar	14

pH = 7.2±0.2

TRYPTICASE SULPHITE NEOMYCINE

Tryptone	15
Autolytic yeast extract	10
Sodium sulphite	1
Ammoniacal iron citrate	0.5
Neomycinesulphate	50
Polymixine B sulphate	20
Agar	13.5

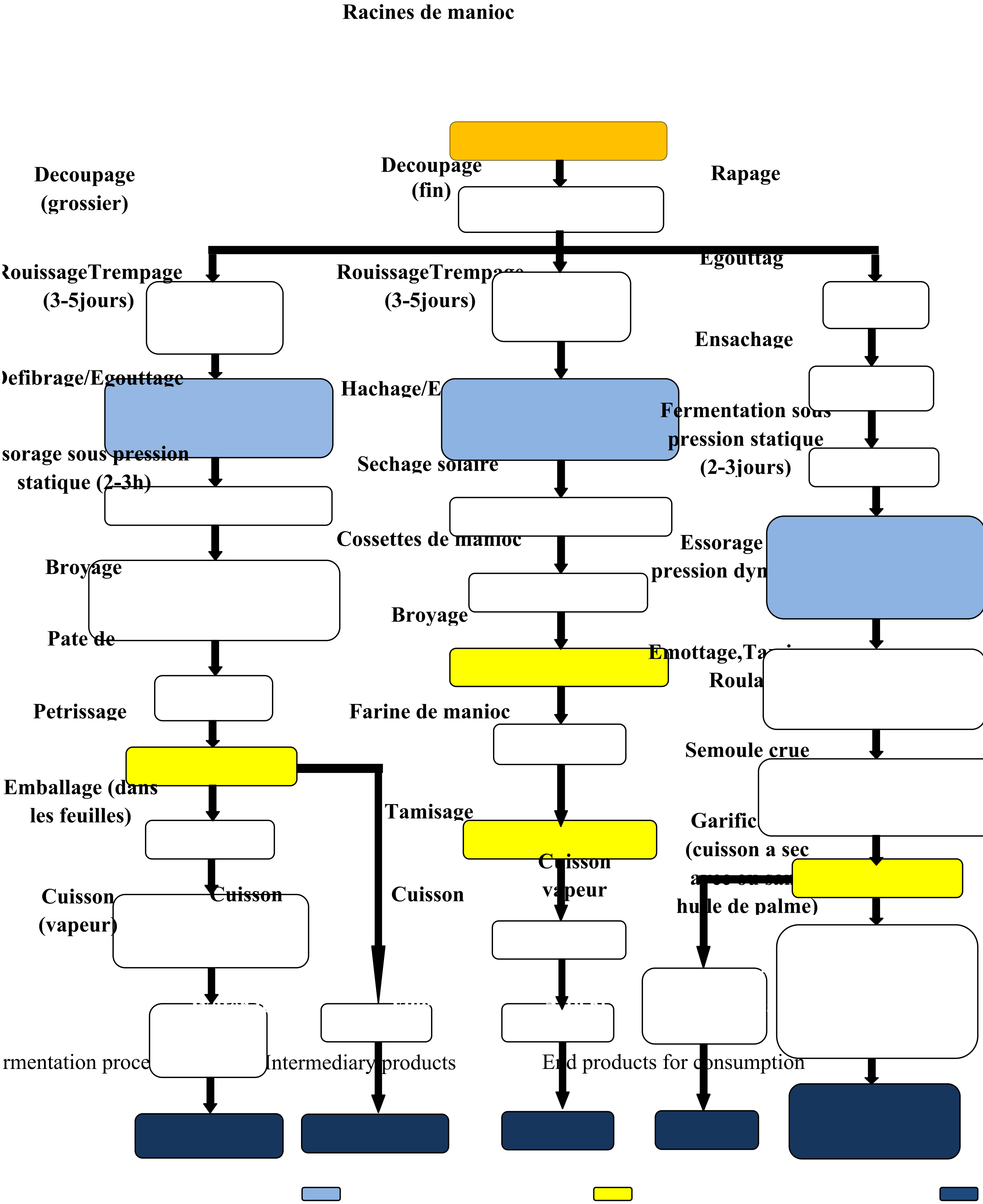
pH = 7.2±0.2

MAC CONKEY GEL:

Bacteriological peptone	20
Bile salts	1.5
Sodium chloride	5
Lactose	10
Crystal violet	0.001
Neutral red	0.03
Agar	15

pH ≈7.1

FLOW CHART FOR THE PRODUCTION OF SOME CASSAVA DERIVATIVES (ESSIA NGANG, 2008)



APPENDIX 4

FORM FOR THE EVALUATION OF CONSUMER EXPECTATIONS

When consuming water fu-fu, there are certain qualities which you take into consideration before making a choice. For each of the quality parameters below indicate the degree to which they influence your choice of water fu-fu (rate on a scale of 1 to 10).

Colour:	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Aroma:	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Smoothness:	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Elasticity:	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Softness:	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Gummy nature:	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Taste:	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**

APPENDIX 5: RESULTS OF MICROBIOLOGICAL ANALYSES OF WATER FU-FU SAMPLES

ANALYSIS	SAMPLE (Log cfu/g)		
	F3,1	F3,2	F5,3
Total Bacillus count	3.28± 0.38	3.89 ± 0.27	7.67± 0.05
Total Coliform count	3.48±0.02	2.37±0.44	2.81± 0.02
ASR	0	1±0.71	0

APPENDIX 6

RESULTS OBTAINED FROM THE EVALUATION OF CONSUMER EXPECTATIONS

CONSUMER	COLOUR	AROMA	SMOOTH NESS	ELASTI CITY	SOFT NESS	GUMMY NATURE	TASTE	
C1	8	9	6	4	7	5	9	
C2	8	9	6	5	5	8	9	
C3	9	10	9	7	10	1	10	
C4	9	7	8	5	6	8	10	
C5	5	4	8	4	9	9	8	
C6	8	9	10	7	7	9	10	
C7	9	9	10	8	5	9	10	
C8	10	7	10	9	10	10	10	
C9	8	8	10	10	9	7	7	
C10	8	2	9	1	7	3	9	
C11	9	8	8	5	7	6	10	
C12	10	1	10	6	10	1	10	
C13	9	5	8	4	7	6	10	
C14	5	9	9	7	9	4	9	
C15	7	6	8	7	8	5	10	
C16	9	7	8	7	6	7	9	
C17	8	8	8	4	6	8	8	
C18	10	9	9	8	9	8	8	
C19	6	9	9	9	5	8	8	
C20	7	8	8	9	6	9	10	Sum
mean	8.1	7.2	8.55	6.3	7.4	6.55	9.2	53.3
% importance	**15.20**	**13.51**	**16.04**	**11.82**	**13.88**	**12.29**	**17.26**	

APPENDIX 7

SUMMARY (AVERAGE SCORES) OF SENSORIAL ANALYSIS

SAMPLE	PARAMETER								
	COLOUR	AROMA	SMOOTH NESS	ELASTI CITY	SOFT NESS	GUMMY NATURE	TASTE	OVERALL ACCEPTABILITY	PQIM
F3,1	6.85	6.69	6.23	6.62	7.04	6.31	6.88	7.2	**6.7**
F3,2	7.38	6.85	6.15	6.27	6.69	5.92	7.08	7.1	**6.7**
F3,3	6.77	6.92	5.54	5.92	6	5.54	6.85	6.7	**6.3**
F4,1	6.54	6	5.62	5.85	6.23	6.08	6.31	6.2	**6.1**
F4,2	6.62	6.08	5.62	5.08	5.85	4.46	5.77	6.1	**5.7**
F4,3	6.54	6.08	5.85	5.08	6.23	5.15	6	6.2	**5.9**
F5,1	6.69	5.85	6.08	5.38	5.92	5.23	5.85	6.2	**5.9**
F5,2	6.77	5.69	5.77	5.34	6.38	5.08	5.31	6.1	**5.8**
F5,3	6.92	6.46	6.77	6.38	7	6.31	6.42	6.9	**6.6**
CONTROL	6.92	5.62	7.23	4.92	7.15	6.31	6.23	6.8	**6.4**