EFFECT OF DIFFERENT PROCESSING CONDITIONS ON THE QUALITY CHARACTERISTICS OF GARI

BY

EHIRIM, CHISOM CHIMDI (B.Sc)
REG NO. (20094698108)

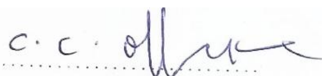
A THESIS SUBMITTED TO THE POSTGRADUATE SCHOOL FEDERAL UNIVERSITY OF TECHNOLOGY OWERRI.

IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF THE DEGREE (MASTER OF SCIENCE) M.Sc IN FOOD SCIENCE AND TECHNOLOGY

MARCH, 2018

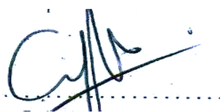
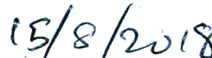
CERTIFICATION

This is to certify that this work "Effect of Different Processing Conditions on the Quality Characteristics of Gari" was carried out by I Ehirim Chisom Chimdi, (Reg. No. 20094698108) in partial fulfillment for the award of the degree of Master of Science (M.Sc) in Food Science and Technology (Food Processing and Technology Option) in the Department of Food Science and Technology of the Federal University of Technology, Owerri.

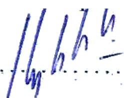


Dr. C.C. Ogueke Date
(Supervisor)

Dr. C.I. Owuamanam Date
(Co-Supervisor)

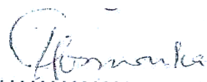
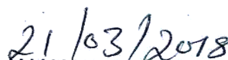
Dr. C. M. Osuji Date
(Head of Department)



Engr. Prof. G. I. Nwandikom Date
(Dean, School of Engineering and Engineering Technology)

....

Prof. (Mrs) N. N. Oti Date
(Dean, Postgraduate School)

Prof. G. I. Onwuka Date
(External Supervisor)

DEDICATION

This work is dedicated to God Almighty for His grace which has ever been sufficient for me throughout the work period.

ACKNOWLEDGEMENT

I sincerely thank my supervisor, Dr. Ogueke C.C whose effort and advice has contributed to the successful completion of this work.

My appreciation also goes to Dr. Owuamanam, C.I., Dr. Nkwoala, C. and other lecturers in the department of Food Science and Technology, FUTO for their support and assistance during the programme.

Words are not really enough to express my gratitude for the love and support from my loving husband Barr. Ojiabo Chimezie. And to my parents and siblings, I appreciate your prayers and encouragement.

TABLE OF CONTENTS

		Page
Title page		i
Certification		ii
Dedication		iii
Acknowledgement		iv
Abstract		v
CHAPTER ONE	INTRODUCTION	1
1.1	Background of the study	1
1.2	Problem statement	2
1.3	Objectives of the research	4
1.4	Justification	4
1.5	Scope of study	5
CHAPTER TWO	LITERATURE REVIEW	6
2.1	Cassava	6
2.1.1	Taxonomy and classification of cassava	6
2.1.2	Nutritive value of cassava	7
2.1.3	History and economic impact of cassava	7
2.1.4	Cassava toxicity and detoxification	9
2.2	Gari	11
2.2.1	Gari production	12
2.3	Processing techniques and their effect on the quality of garri.	14

2.3.1 Tissue disintegration 14

2.3.2 Fermentation 14

2.3.2.1Microorganisms involved in fermentation 14

2.3.2.2Duration of fermentation 15

2.3.2.3Temperature of fermentation 16

2.4 Quality control in garri production 16

2.4.1 Raw material control 16

2.4.2 Processing time and control 17

2.5 Nutritive value of Gari 17

2.6 packaging and storage of Gari 18

CHAPTER THREE MATERIALS AND METHODS 19

3.1 Materials 19

3.1.1 Source of raw materials 19

3.1.2 Equipment and chemicals used 19

3.2 Methods 19

3.2.1 Sample preparation and fermentation 19

3.2.2 Generation of relative humidity 20

3.2.3 Experimental design 20

3.2.4 Determination of chemical analysis 22

3.2.4.1 pH 22

3.2.4.2 Total titrable acidity 22

3.2.4.3 Extraction of linamarase 22

3.2.4.4 Determination of cyanide in fermenting mash 23

3.2.4.5 Determination of free cyanide 23

3.2.5 Determination of proximate composition of gari samples 24

3.2.5.1 Moisture content 24

3.2.5.2 Protein content 25

3.2.5.3 Fat content 26

3.2.5.4 Crude fibre 27

3.2.5.5 Carbohydrate content 27

3.2.6 Determination of functional properties 27

3.2.6.1 Swelling index 28

3.2.6.2 Water absorption capacity 28

3.2.6.3 Bulk density 28

3.2.7 Determination of residual cyanide in gari samples 29

3.2.8 Determination pasting properties in gari samples 29

3.2.8.1 Sensory evaluation 30

3.2.9 Statistical analysis 30

4.1 CHAPTER FOUR RESULTS AND DISCUSSION 31

4.2 Discussion 38

4.2.1 Effect of fermentation variables on the chemical properties of cassava mash during fermentation 38

4.2.1 pH of the cassava mash as affected by temperature, relative humidity and fermentation time 38

4.2.2 TTA of the cassava mash as affected by temperature, relative humidity and fermentation time 39

4.2.3 HCN of the cassava mash as affected by temperature, relative humidity and fermentation time 39

4.2.4 Proximate composition of gari samples as affected by fermentation variables 40

4.2.5 Functional properties of gari samples as affected by fermentation variables 41

4.2.6 pH, TTA and HCN of gari samples as affected by fermentation variables 42

4.2.7 Pasting properties of gari samples 44

4.2.8 Sensory properties of gari samples 47

CHAPTER FIVE

5.1 Conclusion 49

5.2 Recommendation 50

5.3 Contribution to knowledge 50

References 51

Appendix 59

LIST OF TABLES

Table **Page**

Table 3.1 The independent variables and their levels 21

Table 3.2 Combination of the independent variables 21

Table 4.1 pH, TTA and HCN of the cassava mash as affected by temperature, relative humidity and fermentation time 32

Table 4.2 Proximate composition of gari samples 33

Table 4.3 Functional properties of gari samples 34

Table 4.4 pH, TTA and HCN of gari samples 35

Table4.5 Pasting properties of gari samples 36

Table 4.6 Sensory properties of gari sample 37

LIST OF FIGURES

		Page
Figure 2.1	Hydrolysis of linamarin	10
Figure 2.2	Flow diagram of gari production	13

ABSTRACT

The effect of some fermentation variables (temperature, relative humidity and duration of fermentation) on the fermentation of grated cassava mash for gari production and HCN reduction was studied. The proximate composition, functional, chemical, pasting and sensory properties were determined using standard analytical methods. The proximate composition of gari samples ranged; from 10.28-12.79% for moisture, 81.06-83.76% for carbohydrate, 1.84-2.11% for crude protein, 0.94-1.12% for crude fibre and 1.71-2.17% for ash. The pH of the gari samples ranged from 5.62-5.85, TTA 0.34-0.47% and HCN 4.11-7.86mg/kg. The functional properties of the gari samples ranged from 3.50-4.17g/g for water absorption capacity, 3.36-3.62ml/ml for swelling index and 0.47-0.50g/ml for bulk density. The sample fermented at 40°C, 85% relative humidity and 72h (sample 4) had the highest value for protein (2.11%), ash (2.17%) water absorption capacity (4.17g/g) and swelling index (3,62ml/ml). These values were significantly different ($p<0.05$) from the values obtained from the other samples. The HCN content of sample 8(fermented at 40°C, 75%RH, 96h) was found to be the lowest (4.11mg/kg). It also had the lowest pH value at the end of fermentation of the mash. The length of fermentation was observed to have the most significant effect on most of the parameters monitored while temperature had the least effect. However, result of the pasting properties indicated that sample 1(fermented at (30°C, 65%RH and 72h) had the best properties for mouldability. The result of the sensory properties in the overall indicated that sample 4 (fermented at 40°C, 85% RH and 72h) was well accepted by the panelists.

Keywords: Gari, Fermentation variables (Temperature, Relative Humidity, Time), HCN, Functional properties, Chemical properties, Pasting properties, Sensory properties.

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF THE STUDY

Gari is a granular pre-gelatinized cassava starch with a slightly fermented flavour and a slightly sour taste made from grated, fermented, gelatinized fresh cassava roots (Sokari and Karibo, 1992). This partially gelatinized dried cassava product is commonly consumed directly or soaked in cold water with sugar, coconut, roasted peanut, or boiled cowpea as compliments, or as a stiff gel made with hot water and eaten with soup or stew.

The acceptance and popularity of gari in urban and rural areas of West and Central Africa is attributed to its ability to store well, its convenience and ready-to-eat form (Flach, 1990).

A safety concern among the consumers of cassava based products like gari arises from the presence of cyanogenic glucoside, which upon hydrolysis produces cyanohydrin that further breaks down to release hydrogen cyanide- a known plant toxin (Bokanga 1994; Ernesto *et al*., 2002).

Although all the processing steps are important to determining the end quality of gari, however, grating and fermentation remain the critical process steps in gari processing. Hydrolysis is initiated by intimate contact between natural compartmentalized enzyme linamarase and linamarin (Vasconcelos *et al*., 1990), while fermentation is crucial to the development of the characteristic aroma, sour flavour of gari and detoxification of the mash by liberation of free hydrogen cyanide (Achinewhu and Owuamanam, 2001).

1.2 PROBLEM STATEMENT

Gari production till date is carried out at local levels mostly by local women who do so to enhance household food security (Fapojuwe, 2008), and according to Nweke *et al*. (2002), production of gari remains labour-intensive. Large scale production of gari in Nigeria failed probably due to the limited information on processing variables that promote detoxification in cassava, and fermentation to produce unique flavor characteristics associated with gari (Achinewu and Owuamanam, 2001; Nweke *et al*., 2002).

Traditional processing of cassava by fermentation is centered on reduction of cyanide in the resultant product through extended period of fermentation for up to 7days as important strategy for the safety of product (Sanni, 2005). However, the traditionally processed gari contain varied amount of residual cyanide because of the tendency by local processors to shorten the duration of fermentation in order to meet growing market demand (Nweke *et al*., 2002).

It is difficult to understand how cassava and cassava products such as garri can be promoted without giving proper consideration to the fact that it contains cyanogens (linamarin) that liberates poisonous cyanide in the body. Consumption of cassava and its products containing amounts of cyanide can cause acute intoxication, with symptoms of dizziness, headache, nausea, vomiting, stomach pains, diarrhea and sometimes death (Oluwole *et al*., 2003). Since lethal dose is proportional to body weight, children tend to be more susceptible to outright poisoning than adults. In regions where there is iodine deficiency, which causes goiter and cretinism, cyanide intake from cassava exacerbates these conditions (Delange *et al*., 1994). In west Africa particularly Nigeria, there is a disease

called tropical ataxic neuropathy (TAN), which generally occurs in older people who have consumed a monotonous cassava diet over years. TAN is progressive and causes unsteady walking, produces loss of sensation in hands, loss of vision, deafness and weakness (Dulcer *et al*., 2008). Until recently, long term cyanogenic intake was linked with the occurrence of TAN but recent work has shown that the situation may be more complex. Also, when cassava and its products are eaten, most of the ingested cyanide is converted into thiocyanate, a reaction catalyzed by the enzyme rhodanese, which uses up part of the pool of S-containing essential amino acids, methionine and cystein (Cardoso *et al*., 2004). These amino acids are essential in the diet because they can only be obtained from the food consumed. A shortfall of this S-containing amino acid would limit protein synthesis and could cause stunting in growing children, as was found in a study of children in DRC (Dulcer *et al* ., 2008).

It is therefore the object of this work to note new methods of processing and technology towards reducing human cyanide intake.

1.3 OBJECTIVES OF THE RESEARCH

The main objective of this research is to study the effect of different processing conditions on the quality characteristics of garri.

The specific objectives of this research work are as follows;

i. To produce gari at controlled conditions of temperature, relative humidity and time.

ii. To monitor the fermentation process for breakdown and removal of cyanogenic compounds and cyanide.

iii. To determine the proximate composition, functional and pasting properties of the final products.

iv. To determine the sensory attributes of the products.

1.4 JUSTIFICATION

There is need to optimize the local gari processing methods as well as its industrialization especially by reducing the fermentation time and achieving the elimination of cyanide while maintaining gari quality.

This present study considered the variability in the environment and fermentation conditions (temperature, relative humidity and duration of fermentation) during fermentation of cassava mash as they affect quality characteristics of gari and reduction of cyanide.

1.5 SCOPE OF STUDY

This research work covered obtaining the samples, processing it (fermenting the cassava mash at different combined fermentation variables; temperature, relative humidity and time). The samples were analysed for pH, TTA and HCN. Thereafter, the samples were toasted to obtain the final product (gari) which were analysed for proximate, chemical, functional, pasting and sensory properties.

CHAPTER TWO

LITERATURE REVIEW

2.1 Cassava

Cassava (*Manihot esculenta Crantz*) is the most perishable of roots and tubers and can deteriorate within two or three days after harvesting. It is one of the most important staple food crops grown in the tropical Africa, and plays a major role in effort to alleviate the African food crisis because of its efficient production of food energy, year-round availability, tolerance to extreme stress conditions, and suitability to present farming and food system in Africa (Cardoso *et al*., 2005).

2.1.1. Taxonomy and classification of cassava

There is a wide range of cassava varieties which constitute the sweet and bitter cassava varieties. The designation of bitter and sweet varieties depends on taste that is associated with the levels of cyanogenic glucosides mainly linamarin. The bitter cassava (*Manihot utilissima*) has high level of hydrogen cyanide, evenly distributed through the root, which can amount up to 250mg/kg fresh root. It is easily recognized first by its green leaf-stalk and the whitish outer cortical layer of the root (Sirtunga *et al*., 2004). It also has a vegetation period of 12-18 months.

The sweet cassava (*Manihot palmata*) is known by a red leaf stalk and purplish outer cortical layer. In the sweet cassava, the hydrocyanic acid is confined to the skin and outer

layer of the root. It's vegetation period is relatively short usually between 6-9 months (Dulcer *et al.,* 2008).

2.1.2 Nutritive value of cassava

Nutritionally, cassava is one of the principal sources of calorie to human diet, and contributes a nominal quantity of protein and fat. Among the minerals in the tuber, phosphorous and iron predominate with nutritionally significant amount of calcium (33mg per 100g fresh weight).

The tuber is relatively rich in vitamin C (35mg per 100g fresh weight), and contain traces of niacin, thiamine, riboflavin and vitamin A.

The protein of the cassava tuber is rich in arginine, but low in methionine, lysine, tryptophan, phenylalanine and tyrosine. As such, protein in cassava is not only low in quantity, but also poor in quality (Delange *et al*., 1994). Infact an unbalanced diet containing only cassava can lead to nutritional deficiency.

2.1.3 History and economic impact of cassava

Cassava (*Manihot esculenta Crantz*) originated in the Northeast Brazil and Paraguay, and was later assimilated by the West Indians (Cardoso *et al*., 2004). Having begun with these regions, cassava is now cultivated in all tropical regions of the world among which Nigeria is one of them.

Nigeria's cassava production is by far the largest in the world, three times more than the production in Brazil and almost double the production in Indonesia and Thailand (FAO,

2006). In 2002, the Food and Agricultural Organization of the United Nation in Rome estimated cassava production in Nigeria to be approximately 34million tonnes which on comparison with other crops ranks first, followed by yam production 27million tonnes, sorghum 7million tonnes, millet 6million tonnes and rice 5million tonnes (FAO, 2006).

In Nigeria, cassava appears to be the major staple food that matches the population growth. It is a major source of dietary energy for low-income consumers. It also plays a role in providing a stable food base in areas prone to drought and famine. Cassava is predominantly used as food with small amount in agro-allied industrial livestock feed and starch production (Sanni, 2005).

Many traditional foods are processed from cassava roots among which are; flour, dried chips, gari, fufu, farinha, etc. Cassava starch is extensively utilized by most of the food industries to produce ; baked products, confectioneries, canned fruits, jam, preserves, monosodium glutamate (MSG), production of commercial caramel, glucose, dextrose, dried yeast, etc. Non-food uses of cassava starch include; corrugated cardboard, remoistening gum, wall paper industry, textile industry and wood furniture (Moorthy, 1985). 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.

Better processing methods can improve the life-styles and health of rural people through higher processing efficiency, labour saving and reduced drudgery, all of which improve the quality of products.

2.1.4 Cassava toxicity and detoxification

Cassava contain cyanogenic glucosides, mainly linamarin, and in a small proportion, lotaustralin which may be hydrolysed by the endogenous enzyme linamarse to liberate hydrogen cyanide (HCN) (Ernesto *et al*., 2002). According to Bokanga (1994) valine and isoleucine are the precursor in the synthesis of linamarin and lotaustralin respectively. All tissues of cassava contain cyanogenic glucosides. The cyanogenic potential (CNP) of leaves including the petioles is usually the highest in the plant and may be 5 to 20 times of that of the root cortex.

Cassava tubers vary widely in their cyanide content, although most varieties contain 150 – 400mg HCN per kg fresh weight (Padmaja, 1995). Cyanide doses of 50-100mg are reported to be lethal to adults whereas, acute poisoning occurs scarcely. Several diseases are associated with the consumption of cassava products if inadequately processed, such as tropical ataxic neuropathy, endemic goiter, spastic paralysis and konzo (Lambien *et al*, 2004).

As such, lethal dose of cyanide is usually detoxified by the body to the low toxic metabolite thiocyanate, which is excreted in the urine. A chronic overload of thiocyanate

in conjunction with low iodine intake however, results in goiter and, in extreme cases, cretinism in children (Padmaja, 1995).

The different techniques of processing cassava have one common goal, to obtain a safe food. The traditional methods usually include; chipping, soaking, fermentation, cooking, steaming, drying, and roasting. They all permit the enzyme linamarase to interact with the cyanogenic glycoside, thereby bringing about the hydrolysis of linamarin.

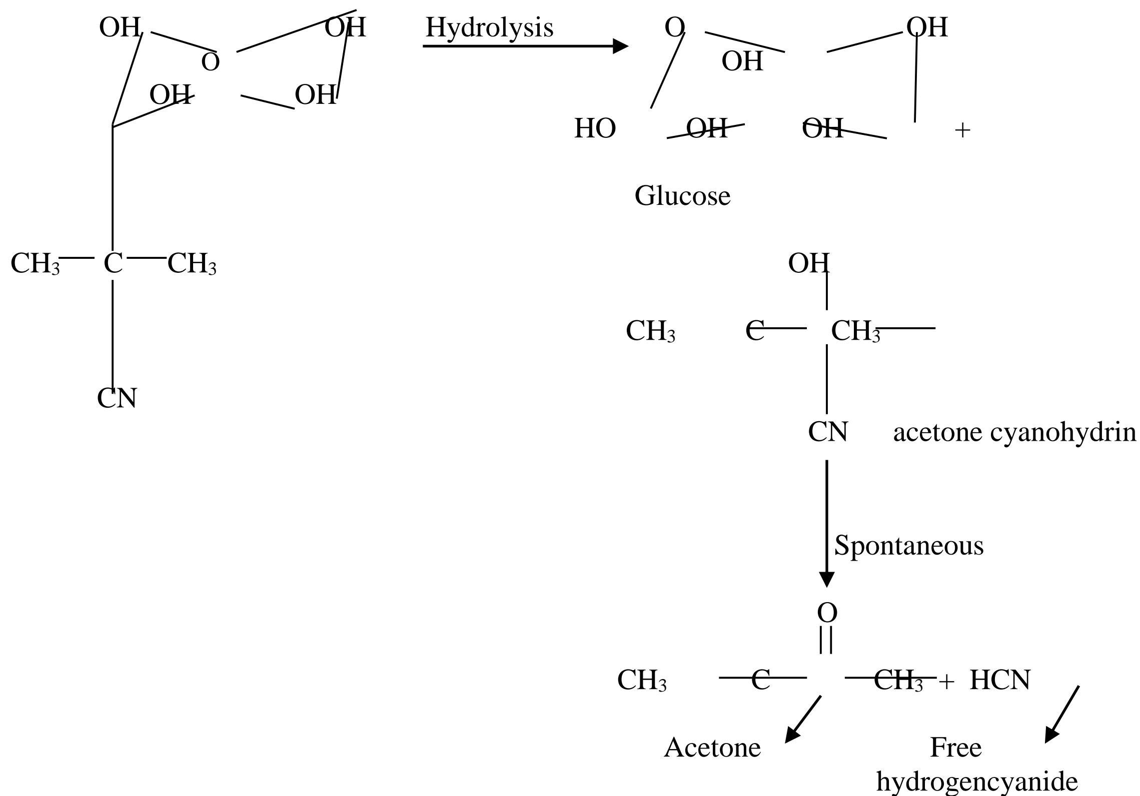


Fig 2.1 Hydrolysis of linamarin.
Source: (Okaka, 2005).

In the intact cassava tissue, endogenous linamarin is segregated from the endogenous enzyme linamarase. However, when the root is bruised, cut, grated or otherwise

disintegrated, linamarin and endogenous linamarase come in contact resulting in the hydrolysis of linamarin to yield hydrogen cyanide (Okaka, 2005).

Bound and free cyanide levels in cassava products must be monitored as positive tool for predicting product wholesomeness. Any deviation in conduct and timing of the process steps may adversely affect the detoxification value of the process. For example, the process whereby little or no fermentation time is allowed prior to dewatering during garri production results in the product having higher than normal level of bound cyanide and so must be discouraged (Okaka, 2005).

2.2 Gari

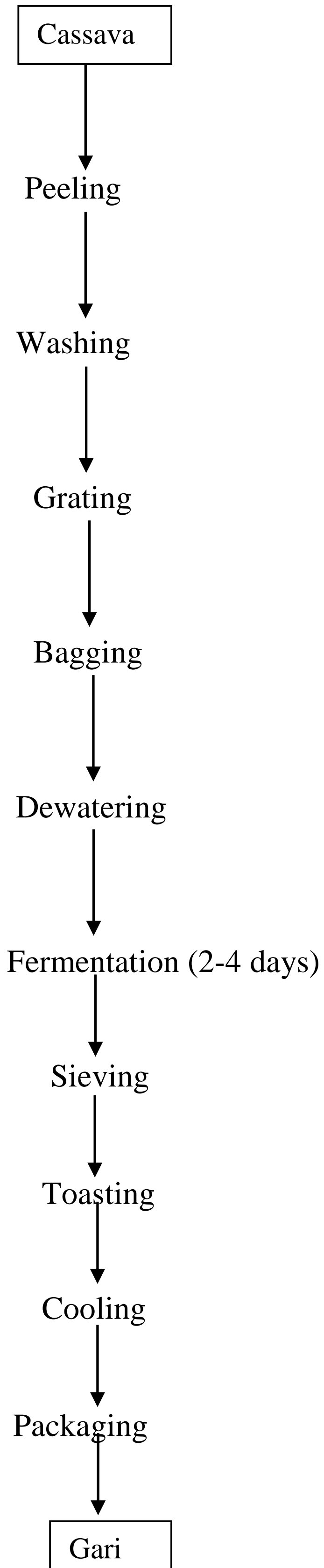
Gari is a fermented, pre-gelled grit made from cassava, and is the most popular form in which cassava is consumed in West Africa (Okaka, 2005). It is a stable, ready-to-eat food, well suited to urban and rural markets. Gari is principally consumed in the main meal with soup or stew. It can also be eaten as snack when soaked in cold water or milk, with sugar, roasted groundnut or coconut. Gari contributes up to 60% of the total caloric intake in West Africa, where an average of 150g per person, per day is consumed (Okaka, 2005).

In Nigeria gari is mainly produced on a small scale and marketed by women. It is an important source of income in the rural areas. Gari variability exists in consumer perception of gari quality and it is difficult to establish optimum values for the different quality parameters. However, in general, consumers prefer crisp, fine grained, slightly soured product with good swelling power in water, and a lightly toasted colour (Flach, 1990).

2.2.1 Gari Production.

The production of gari involves some processing steps in which all are important in determining the end product quality. Some of them are mechanical (peeling, grating, sieving, and dewatering) while others like fermentation and garification involve some physical and chemical modification, which improve detoxification and digestibility.

The traditional processing of gari described by Okaka (2001) is as follows: Cassava is peeled, washed, grated and packed in cloth bags, which are then subjected to heavy pressing for 2-4 days by weights placed on the product contained in the bags. A simultaneous dewatering and fermentation occur during this period, yielding a pulp cake which when rasped gives a grain mass. This mass is toasted in a hot pan over a wood fire until the starch gelatinized and the moisture content reduced to 10-15%. The mash must be stirred constantly to avoid sticking or burning. Palm oil may be added to facilitate this operation and impart a yellow colour to the final product.


Cassava
Peeling
Washing
Grating
Bagging
Dewatering
Fermentation (2-4 days)
Sieving
Toasting
Cooling
Packaging
Gari

Source: (Okaka, 2001)

Fig 2.2: Flow diagram of gari production

2.3 Processing Techniques and Their Effect on The Quality Of Gari

2.3.1 Tissue disintegration (grating)

Tissue disintegration in the presence of excess moisture during grating permits the rapid hydrolysis of glucosides, effectively reducing both free and residual cyanide in the gari product. The observations of Maduagwu (1983) and Vasconcelos *et al* (1990) indicate that the release of endogenous linamarase during grating was one of the important steps in detoxification.

2.3.2 Fermentation

Fermentation is crucial to the detoxification of cassava mash and the development of the characteristic aroma and sour flavor of gari, imparted mainly by lactic acid bacteria, which produce lactic acid and volatiles such as; aldehydes, diacetyl, esters and ethanol (Owuamanam, *et al* 2011).

The fermentation of the grated mash occurs in two stages; *Corynebacterium manihot* breaks down the starch to produce organic acids which decrease the pH and this lead to the hydrolysis of linamarin during which gaseous hydrogen cyanide is evolved. This stage is completed within 24hrs. The production of organic acids stimulates the growth of a fungus *Geotricum candida*, which produces the aldehydes and esters responsible for the characteristic flavor of gari (Ihekoronye and Ngoddy, 1985).

2.3.2.1 Microorganisms involved in gari production

Early studies (Collard & Levi, 1959) of the microbiology of the gari fermentation reported that a *Corynebacterium sp* and *Geotricum candida* were responsible for acid and flavor production Owuamanam, *et al* (2011) found however, that of the microorganisms isolated from gari, *Lactobacillus plantarrium* produced the most typical gari flavor. Okafor (1990) isolated organisms of five genera from the gari fermentation; *Leuconostoc, Alcaligenes, Corynebacterium Lactobacillus and Candida.* In a similar type of study on gari, Westby and Twiddy (1992) observed that during gari production (fermentation) lactic acid bacterium was found to be dominant. Overall equal number of homo and hetero-fermentative lactic acid bacteria was isolated however, homo-fermentative organisms dominated in the early stages of the process and hetero-fermenters in the later stage.

2.3.2.2 Duration of fermentation in gari production

The time allowed for fermentation has been found to be critical. Short fermentation period results to incomplete detoxification process thereby producing a toxic gari product, while too long fermentation period produces a product with a strong sour taste and a poor textural quality (Azam Ali *et al*., 2003).

Earlier studies by Irtwange and Achimba (2009) on the effect of the duration of fermentation on the quality of gari indicated that there was a highly significant effect of the duration of fermentation on the moisture content, ash, crude fibre, fat, crude protein and HCN. The result of their study further expressed that the moisture content, ash, crude fibre and crude protein increased with increase in the duration of ferentation. Similarly,

Owuamanam, *et al*. (2011) found that duration of fermentation significantly affected the physicochemical and sensory quality of gari, and that the duration of fermentation improved the appearance, taste and general acceptability of the resultant gari.

2.3.2.3 Temperature of fermentation

Owuamanam *et al*. (2011) in their study on the effect of temperature of fermentation on gari quality revealed that maintaining the temperature above the ambient, contributed to volatilization of residual cyanide, and also gave better performance in the physicochemical and sensory properties. Furthermore, the result suggested that the optimum temperature for fermentation in gari processing is between 35-40°C. This is due to the fact that the optimum fermentation temperature enhances the cyanide reduction and the activities of microbes for the production of useful metabolites (Owuamanam *et al*, 2011).

2.4 Quality control in gari production

2.4.1 Raw material control

Fresh (1-2 days old) and healthy cassava roots are the best raw material for producing gari. They carry a large amount of soil (especially during the rainy season), which is the source of microbial inoculation and therefore two washing stages are desirable. Double washing before and after peeling reduces the microbial count in gari product (Awan, 1983).

2.4.2 Process time and control

The optimum period for the fermentation should be at least 3days after an experiment which was carried out on the effect of process time and control of gari quality by Irtwange & Achimba (2009). It is important to note that the small daily change in pH accounted for the desirable changes in aroma and taste of gari (Irtwange & Achimba, 2009). The mash must be toasted immediately after dewatering process or drastic change in pH will occur (Awan, 1983).

Adequate roasting is important to reduce cyanide content. It is not advisable to mill gari after cooling. Sieving it after roasting is sufficient to produce even granules since granules rather than powdery consistency is desired by consumers.

The maintenance of equipment is easier if non-rusting metal is used to construct the grater and sieves. Cleaning schedules should be adhered to. Also during stages of processing, personal hygiene must be monitored.

2.5 Nutritive value of gari

Gari like the raw material from which it is made from is a nutritionally poor diet (Owuamanam, 2010). It is low in protein, fats, ash, and fibre, but it is a valuable source of carbohydrate and energy. Gari is low in methionine, lysine and tyrosine but high in arginine (Onyenuga, 1985). In diet however, gari is always combined with other nutritious food stuffs which enhance their nutritional value. For example, traditionally, gari is eaten with vegetable soup with meat or fish. As a snack, is taken with groundnut, coconut, fish or meat.

2.6 Packaging and storage of gari

A well processed and packaged gari with moisture content of about 8-10% can be stored for about one year, with little or minimal alteration in its organoleptic properties (Bencini, 1991). Gari for use within the shortest possible time may be dried up to about 12-14% moisture content (Okaka, 2001).

Upgraded packaging materials for gari consists of jute sacks, which are sometimes lined with polyethylene pouches. The pouches may either be heat sealed or by twisting and tying it with twine.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Materials

3.1.1 Source of raw material

The fresh bitter cassava roots (97/4779) used in the study were obtained from National Root Crop Research Institute, Umudike, Umuahia, Nigeria.

3.1.2 Equipment and chemicals used

All equipments and chemicals used for the study were obtained from National Root Crops Research Institute (NRCRI) Umudike and Reliable research laboratory services Umuahia, Abia State. All chemicals used were of analytical grade.

3.2 Methods

3.2.1 Sample preparation and fermentation

The cassava tubers were washed, drained and peeled. Working in a sterile hood, the tubers were rapidly grated into a sterile container with a sterile hand grater. Five hundred grams (500g) of the sample was weighed rapidly into small jute bags and tied with fishing line thread. They were then put in incubators set at the appropriate temperatures (30^oC, 35^oC and 40^oC), relative humidity (65%, 75% and 85%) and allowed to ferment for the desired length of time (48hours, 72hours and 96hours).

3.2.2 Generation of relative humidity (RH)

The various relative humidity were generated by using the method described by Ogueke *et al*. (2013). These weres as follows;

i) 65% RH was generated by dissolving 50g of anhydrous $NaNO_3$ in 33.3ml of water at 100^oC.

ii) 75% RH was generated by dissolving 20g of NaCl in 50ml of water at 100^oC.

iii) 85% RH was generated by dissolving 25g of KCl in 50ml of water at 100^oC.

The salt solutions were put in the incubators to create the required relative humidity in the environment of fermentation.

3.2.3 Experimental design

A Box Behnken rotable response (Lawson and Madrigal, 1994) for k = 3 was employed to study the effect of the independent variables on the fermentation process. The variables were of three levels (Tables 1 and 2).

Table 3.1: The independent variables and their levels

Independent variables	Variable levels		
	-1	**0**	**+1**
Temperature (x_1)	30	35	40
Relative Humidity (x_2)	65	75	85
Duration of fermentation (x_3)	48	72	96

Table 3.2: Combination of the independent variables.

Run	x_1	x_2	x_3
1	-1	-1	0
2	+1	-1	0
3	-1	+1	0
4	+1	+1	0
5	-1	0	-1
6	+1	0	-1
7	0	0	+1
8	+1	0	+1
9	-1	-1	-1
10	0	+1	-1
11	0	-1	+1
12	0	+1	+1

Controlled sample was ferment ed naturally as is done by producers

3.2.4 Chemical analysis

Samples were collected from the fermenting mash on 24 hour basis for analysis. The parameters analyzed for were: pH, total titrable acidity and cyanide content of fermenting mash.

3.2.4.1 pH

The pH of the fermenting mashes was determined using the methods described in AOAC (1990). Ten grams (10g) of the samples were put into 200 ml beaker and 100 mL of distilled water added to it. The pH was then measured using a standardized pH meter (Prazisions pH meter ES10 model).

3.2.4.2 Total titrable acidity (TTA)

Ten grams of sample was homogenized in 200ml of distilled water and filtered using Whatman filter paper. 10ml (mililitre) of filtrate was transferred into a 250ml conical flask. Two (2) drops of phenolphthalein was added and titrated against 25ml of 0.1M NaOH solution until the mixture turned pink. The titre volume was recorded and the percentage (%) titrable acidity (TTA%) as lactic acid was calculated by multiplying the titre volume by 0.09 (Bainbridge *et al*., 1996).

3.2.4.3 Extraction of linamarase:

The method described by Ahaotu *et al*. (2013) was used. Two hundred grams (200g) of fresh cassava peels were homogenized in 160ml of 0.1M acetate in a blender for 3minutes. The homogenate was centrifuged at 10000xg for 30 minutes. The supernatant liquid was

brought to 60% saturation of $(NH_4)_2SO_4$ by adding 724g of $(NH_4)_2SO_4$ in 1600mL supernatant. The salt was added slowly with continuous gentle agitation.

The precipitate was collected by centrifugation at 10000xg for one hour. The supernatant was discarded and the precipitate dissolved in $150ml$ of phosphate buffer (pH 6.0) before freezing.

3.2.4.4 Determination of cyanide in fermenting mash

The free cyanide was determined as described by O'Brien *et al*. (1991). Fifty grams (50g) of sample was homogenized in $200ml$ of extraction medium, which was previously prepared by adding $6.75ml$ of H_3PO_4 to $200ml$ of distilled water. The homogenizer was operated for 15 seconds at low speed, then 2 minutes at high speed with 1 minute rest in between periods. The sample was subsequently centrifuged for 10 minutes at 4000xg. The supernatant was collected for analysis for free cyanide (HCN).

3.2.4.5 Determination of free cyanide

$0.1ml$ of sample extract was mixed with $3.9ml$ of phosphate buffer (pH 4.0). Then $0.1ml$ of linamarase enzyme was added and incubated for 15 minutes at 30°C. Thereafter $0.6ml$ of 0.2M NaOH was added and left for 5 minutes after which, $2.5ml$ of phosphate buffer (pH 6.0) was added. Subsequently, $0.2ml$ of chloroamine-T was added to the test tube already containing 4.0ml of buffered extract to stabilize the colour formation. The

content was mixed and the test tubes placed in iced water bath for 5 minutes and transferred to the fume cupboard. Then $0.8ml$ of pyridine/pyrazolone reagent was added and left for 90 minutes. A series of standards ranging from 0-1.6μg of HCN were prepared and color developed. The absorbance of both standards and sample were spectrophotometrically read at 620nm.

The cyanide content of the sample was determined from the standard calibration curve. Amount of cyanide in 100g sample was computed using the formula:

$$mg/kg\ cyanide = \frac{{}^{\mu g}/_{ml}\ of\ cyanide\ X\ final\ volume\ (ml)\ X\ 10}{sample\ wt} \ldots\ldots\ldots\ldots\ldots\ldots\ldots..3.1$$

where: $\mu g/ml$ of cyanide is obtained from calibration curve

Final volume --- volume of sample measured from filtered extract

Sample weight --- weight of sample extracted.

3.2.5 Determination of Proximate Composition of the gari samples

At the end of fermentation the various samples were toasted over fire to obtain ‘gari’.

The proximate analysis of the final product (gari) was carried out according to the methods outlined by the Association of Official Analytical Chemists (A.O.A.C, 1990).

3.2.5.1 Moisture content

Two grams (2g) of each sample was weighed into a crucible. The crucible and its sample content were dried in the oven at 105°C for 3 hours.

It was cooled in a desicator and re-weighed. The weight was recorded while the sample was returned to the oven for further drying. The drying, cooling and weighing was repeatedly done until a constant weight was obtained.

% moisture content was calculated as;

$$\% \text{ moisture} = \frac{W_{2-W_3}}{W_{2-W_1}} \ x \ \frac{100}{1} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.2$$

Where

W_1 = weight of dried crucible
W_2 = weight of crucible + sample before drying
W_3 = weight of crucible + sample after drying to a constant weight.

3.2.5.2 Protein content

Two grams (2g) of the sample was mixed with $10ml$ of concentrated sulphuric acid in a kjedahl digestion flask. A tablet of selenium catalyst was added to it and the mixture was digested under a fume cupboard until a clear solution was obtained. In a separate flask, the acid and other reagent were digested but without the sample to form the blank control. The entire digest were carefully transferred to a $200ml/vol$ flask using distilled water and made up to a mark in the flask. $10ml$ portion of each digest was mixed with equal volume of 45% NaOH solution in kjedahl distilling unit. The mixture collected into $10ml$ of 4% boric acid solution containing 2 drops of mixed indicator. A total of $50ml$ distillate was obtained and titrated against 0.02M H_2SO_4 solution.

The nitrogen content was calculated as shown below;

$$\% \ N_2 = \frac{(100 \ X \ n \ X \ 14 \ vf)}{w \ X \ 100 \ X \ va} \quad T \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots . .3.3$$

Where

W = weight of sample analysed (g)

n = concentration of the conc. H_2SO_4
vf = total volume of digest (m^3)
va = volume of digest distilled (m^3)
T = titre value blank
% crude protein = % N_2 X 6.25
Where 6.25 is the conversion factor.

3.2.5.3 Fat content

Two grams (2g) of the sample was wrapped in a pooms paper (whatman No.1 filter paper). The wrapped paper was put in a soxhlet flask containing 200ml of ethanol. The upper end of the reflux flask was connected to a condenser. By heating the solvent in the flask through electro thermal heater, it vaporizes and condensed into the reflux flask.

Soon the wrapped sample was completely immersed in a solvent and remains in contact with it until the flask filled up and siphoned over thus carrying oil with it from the sample down to the boiling flask. The process was allowed on repeatedly for 4 hours after which the sample was removed and reserved for crude fibre analysis. The solvent was recorded and the extraction flask with its oil content was dried in the oven at 60°C for 30minutes (i.e. to remove any residual solvent). After cooling in a desicator, the flask was rewashed. The weight of the oil extracted was determined and expressed as a percentage of the sample weight;

$$\% \text{ fat} = \frac{W_2 - W_1}{W_3} \; X \; \frac{100}{1} \qquad \ldots 3.4$$

Where

W_2 = weight of flask + oil
W_1 = weight of empty flask
W_3 = weight of sample used

3.2.5.4 Crude fibre

Two grams (2g) of the sample was defatted during fat analysis. The defatted sample was boiled in 200ml of 1.25% H_2SO_4 solution under reflux for 30minutes. The sample was washed with several portions of hot (boiling) water using a two-fold muslin cloth to trap the particles (residue). The residue was carefully transferred back to the flask and 200ml of 1.25% NaOH solution was added to it. Again the sample was boiled for 30minutes and washed as before with hot water. Then it was transferred to a weighed porcelain crucible and dried in the oven at 105°C for 3 hours. After cooling in a desicator, it was weighed and then put in a muffle furnace and burnt at 550°C for 2 hour until it became ash. Again, it was cooled in a desicator and reweighed.

$$\% \text{ crude fibre} = \frac{W_{2-}W_3}{W_1} \; X \; \frac{100}{1} \ldots \ldots \ldots 3.5$$

Where

W_2= weight of crucible + sample after washing

W_3= weight of crucible + sample as ash

3.2.5.5 Carbohydrate content

Carbohydrate content was determined by the difference method. This was done by summing up the % moisture, %protein, %fat, %ash and %crude fibre contents and then subtracting their sum from 100. It was also expressed in percentage (%).

3.2.6 Determination of functional properties of the gari samples:

The following functional properties of the gari samples were determined:

3.2.6.1 Swelling index

The swelling index of the samples was determined by the method described by Owuamanam, *et al* (2011). Ten grams (10g) of the sample was transferred into a clean, dried, calibrated measuring cylinder. The gari was gently leveled by tapping the cylinder and the initial volume recorded. 50 ml of distilled water was poured into the cylinder and allowed to stand for 4h. The value for swelling index (SI) was taken as the multiples of the original volume.

3.2.6.2 Water absorption capacity (WAC)

The method as described by Owuamanam, *et al* (2011) was followed;

One gram (1g) of gari was weighed into an already weighed clean dried centrifuge tube. 20ml of distilled water was poured into the centrifuge tube and stirred thoroughly; centrifuge at a speed of 3500 rpm for 45minutes. The supernatant was discarded and the tube and its content reweighed. The gain in mass was taken as the water absorbed.

3.2.6.3 Bulk density

The method of Sanni *et al* (2001) was followed. Ten (10 g) grams of the gari were transferred into $50ml$ measuring cylinder. The cylinder was tapped repeatedly for 5 minutes. The bulk density of gari was calculated as the mass of gari over the volume at the end of tapping. The mean value was recorded from triplicate determinations.

3.2.7 Determination of residual cyanide of the gari samples

This was done as described by Owuamanam *et a*l (2011). Thirty grams (30g) of gari was milled and homogenized with $250ml$ of 0.1M otthophosphoric acid. The homogenate was centrifuged and the supernatant taken as the extract; 0.1 ml of the enzyme was added into 0.6 ml of the extract. 3.4 ml of acetate buffer (pH 4.5) was added and stirred to mix, after which 0.2 ml of 0.5% chloramin-T and 0.6 ml of colour reagent were added and allowed to stand for 15 minutes for colour development. The absorbance value was obtained at 605 nm wavelength against a blank similarly prepared containing all reagents and 0.1 ml phosphate buffer instead of KCN.

The data from the standard were used to obtain a standard curve and its slope (b) by plotting absorbance values (Y-axis) against standard concentration (X-axis). The unknown mean absorbance (A) and the weight of the sample (W) were used to calculate the residual cyanide, using the formula;

Residual cyanide = $A\ x\ 250\ x\ 0.4151\ b\ x\ W$---------------------------3.6

Unit = mg HCN equivalent kg^{-1}

Where A---------- mean absorbance

b----------- slope

W--------- weight of sample

3.2.8 Determination of pasting properties of the gari samples

The pasting properties were determined using the Brabender Visco-amylograph as described by Almanza (1988).

3.2.8.1 Sensory Evaluation:

The gari samples which were produced at different combinations of fermentation variables were made into a stiff gel (eba) by pouring 20g of gari sample into 50ml of water boiled at 100°C and then turned to form a stiff gel. Each of the stiff gel (eba) samples were presented in clean plates all at once and assessed. The samples were evaluated for quality acceptability (appearance, texture, taste, aroma and general acceptability) on a 9-point hedonic scale of like extremely = 9, like very much = 8, like moderately = 7, like slightly = 6, neither like nor dislike = 5, dislike = 4, dislike moderately = 3, dislike very much = 2 and dislike extremely = 1 (Watt *et al*., 1985). A 20 member semi-trained panel from the Department of Food Science and Technology, Michael Okpara University of Agriculture Umudike, Abia state was used for the sensory evaluation. Data collected from the evaluation were statistically analyzed

3.2.9 Statistical Analyses

The data obtained from the study were analyzed using Analysis of Variance (ANOVA) and the means separated using Fisher's Least Significant Difference (LSD). The data was processed using Microsoft Excel (2007).

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 RESULTS

Tables 4.1 to 4.8 shows the effect of fermentation variables (temperature, relative humidity and time) on the pH, TTA and HCN of cassava mash, the proximate, functional, chemical, pasting and sensory properties of gari.

Table 4.1 pH, TTA and HCN of the cassava mash as affected by temperature, relative humidity and time of fermentation.

Samples	pH	TTA(%)	HCN(mg/kg)
1	5.02[b]	0.81[a]	47.0[f]
2	4.71[cd]	0.76[b]	48.9[e]
3	4.72[cd]	0.72[bc]	46.8[g]
4	4.84[bc]	0.69[cd]	46.9[g]
5	5.45[a]	0.63[d]	53.8[c]
6	5.48[a]	0.66[cd]	55.1[a]
7	4.62[d]	0.81[a]	43.8[i]
8	4.65[d]	0.83[a]	43.6[ij]
9	5.36[a]	0.68[cd]	51.9[d]
10	5.43[a]	0.63[d]	54.1[b]
11	4.60[d]	0.80[a]	43.2[j]
12	4.52[d]	0.85[a]	42.8[k]
Control	4.68[d]	0.79[a]	44.0[h]
LSD	**0.21**	**0.07**	**0.48**

1,2,3 ….. values on the same column with the same superscript are not significantly different, abc…. values on the same row with the same superscript are not significantly different

sample1 = 30°C, 65RH, 72h
sample2 = 40°C, 65RH, 72h
sample3 = 30°C, 85RH, 72h
sample4 = 40°C, 85RH, 72h
sample5 = 30°C, 75RH, 48h
sample6 = 40°C, 75RH, 48h
sample7 = 30°C, 75RH, 96h
sample8 = 40°C, 75RH, 96h
sample9 = 30°C, 65RH, 48h
sample10 = 35°C, 85RH, 48h
sample11 = 35°C, 65RH, 96h
sample12 = 40°C, 85RH, 96h
sample13 = control.

Table 4.2: Proximate composition of gari samples.

Sample/Run	Moisture content (%)	Ash (%)	Crude fibre (%)	Crude protein (%)	Fat (%)	Carbohydrate (%)
1	10.77^{g}	1.90^{d}	1.05^{c}	1.95^{d}	0.85^{b}	$83.48^{a,b}$
2	11.92^{c}	1.85^{f}	0.98^{d}	1.93^{d}	0.82^{c}	82.50^{e}
3	11.81^{c}	1.92^{c}	1.04^{c}	2.07^{c}	$0.79^{c,d}$	82.38^{e}
4	12.79^{a}	2.17^{b}	1.05^{c}	2.11^{b}	0.83^{b}	81.06^{g}
5	$10.88^{f,g}$	1.71^{k}	1.08^{b}	1.88^{e}	0.81^{c}	83.65^{a}
6	10.76^{g}	1.78^{k}	1.12^{a}	1.84^{h}	0.75^{f}	83.76^{a}
7	$11.09^{e,f}$	1.75^{j}	$0.95^{e,f}$	1.90^{e}	0.74^{f}	83.58^{a}
8	11.49^{d}	1.85^{f}	0.96^{e}	1.94^{d}	0.71^{g}	83.05^{c}
9	10.28^{g}	1.82^{g}	$1.03^{c,d}$	$1.85^{e,f}$	0.82^{c}	83.73^{a}
10	11.14^{e}	1.80^{h}	1.09^{b}	1.89^{e}	0.85^{b}	$83.24^{b,c}$
11	11.27^{de}	1.85^{f}	0.94^{f}	1.90^{e}	$0.83^{b,c}$	$83.23^{b,c}$
12	12.53^{b}	1.82^{g}	0.95^{f}	1.89^{f}	0.91^{a}	81.95^{f}
13(control)	11.77^{c}	1.88^{e}	1.03^{d}	1.88^{e}	0.68^{h}	82.85^{d}
LSD	0.31	0.05	0.03	0.04	0.03	0.36

a,b,c….. values on the same column with the same superscript are not significantly different ($p>0.05$)

sample1 = 30°C, 65RH, 72h
sample2 = 40°C, 65RH, 72h
sample3 = 30°C, 85RH, 72h
sample4 = 40°C, 85RH, 72h
sample5 = 30°C, 75RH, 48h
sample6 = 40°C, 75RH, 48h
sample7 = 30°C, 75RH, 96h
sample8 = 40°C, 75RH, 96h
sample9 = 30°C, 65RH, 48h
sample10 = 35°C, 85RH, 48h
sample11 = 35°C, 65RH, 96h
sample12 = 40°C, 85RH, 96h
sample13 = control.

Table 4.3: Functional properties of the gari samples.

Sample/Run	Bulk density (g/ml)	Water absorption capacity (g/g)	Swelling index (ml/ml)
1	0.49^{b}	$3.94^{b,c}$	$3.45^{,e}$
2	0.48^{d}	4.08^{b}	3.56^{b}
3	0.49^{b}	$4.10^{a,b}$	3.56^{b}
4	0.50^{a}	4.17^{a}	3.62^{a}
5	$0.47^{e,f}$	3.65^{e}	3.36^{g}
6	0.49^{b}	3.75^{d}	3.41^{f}
7	0.48^{d}	3.58^{f}	3.38^{g}
8	$0.47^{e,f}$	3.79^{d}	3.45^{e}
9	$0.48^{e,f}$	3.61^{f}	3.42^{f}
10	$0.47^{e,f}$	3.50^{f}	3.36^{g}
11	0.48^{d}	3.77^{d}	3.48^{d}
12	0.49^{c}	3.80^{d}	3.45^{e}
13	0.48^{d}	3.85^{d}	3.50^{c}
LSD	0.03	0.09	0.04

a,b,c…… values on the same column with the same superscript are not significantly different ($p>0.05$).

sample1 = 3 0°C, 65RH, 72h
sample2 = 40°C, 65RH, 72h
sample3 = 30°C, 85RH, 72h
sample4 = 40°C, 85RH, 72h
sample5 = 30°C, 75RH, 48h
sample6 = 40°C, 75RH, 48h
sample7 = 30°C, 75RH, 96h
sample8 = 40°C, 75RH, 96h
sample9 = 30°C, 65RH, 48h
sample10 = 35°C, 85RH, 48h
sample11 = 35°C, 65RH, 96h
sample12 = 40°C, 85RH, 96h
sample 13 = control

Table 4.4: pH, TTA and HCN of gari samples.

Sample/Run	pH	Total titrable acidity(%)	HCN(mg/kg)
1	5.65^{e}	0.38^{d}	4.53^{g}
2	5.62^{d}	0.38^{d}	4.82^{f}
3	5.65^{c}	0.39^{c}	4.31^{g}
4	5.66^{c}	0.39^{c}	4.77^{f}
5	5.85^{a}	0.34^{g}	7.27^{b}
6	5.84^{b}	0.35^{f}	7.12^{b}
7	5.65^{f}	0.42^{e}	4.19^{i}
8	5.60^{g}	$0.41^{e,f}$	4.11^{i}
9	5.70^{b}	0.35^{f}	7.11^{b}
10	5.85^{a}	0.34^{g}	7.86^{a}
11	5.68^{c}	0.47^{a}	4.27^{e}
12	5.65^{c}	0.45^{b}	4.28^{e}
13	5.75^{c}	0.40^{c}	5.18^{c}
LSD	0.03	0.03	0.55

a,b,c…. values on the same column with the same superscript are not significantly different ($p>0.05$)

sample1 = 30°C, 65RH, 72h
sample2 = 40°C, 65RH, 72h
sample3 = 30°C, 85RH, 72h
sample4 = 40°C, 85RH, 72h
sample5 = 30°C, 75RH, 48h
sample6 = 40°C, 75RH, 48h
sample7 = 30°C, 75RH, 96h
sample8 = 40°C, 75RH, 96h
sample9 = 30°C, 65RH, 48h
sample10 = 35°C, 85RH, 48h
sample11 = 35°C, 65RH, 96h
sample12 = 40°C, 85RH, 96h
sample 13 = control

Table 4.5: Pasting properties of gari samples

Sample/Run	Peak1 (CP)	Trough1 (CP)	Breakdown viscosity (CP)	Final viscosity	Setback viscosity	Peak time	Pasting temp.
1	254.17	249.92	8.25	377.17	131.25	4.87	80.12
2	244.92	150.67	94.25	371.00	220.33	5.00	80.66
3	161.92	100.57	-61.35	232.92	71.00	4.58	81.33
4	164.92	100.33	-64.59	227.33	62.41	4.77	80.33
5	273.08	228.25	44.83	341.50	113.25	5.20	80.66
6	249.00	218.17	30.83	368.33	150.17	4.93	80.46
7	247.75	216.17	2.58	327.17	111.00	5.00	82.55
8	270.17	233.20	36.25	372.42	138.50	4.87	80.43
9	268.17	205.83	62.33	338.92	133.08	5.07	81.42
10	165.30	108.08	-57.22	236.42	71.12	4.36	80.20
11	276.33	24.33	36.00	318.30	151.50	5.00	80.43
12	234.33	205.00	29.42	311.92	106.92	5.13	80.78
13	169.42	109.08	-60.34	230.57	61.15	5.02	80.47

sample1 = 30ºC, 65RH, 72h
sample2 = 40ºC, 65RH, 72h
sample3 = 30ºC, 85RH, 72h
sample4 = 40ºC, 85RH, 72h
sample5 = 30ºC, 75RH, 48h
sample6 = 40ºC, 75RH, 48h
sample7 = 30ºC, 75RH, 96h
sample8 = 40ºC, 75RH, 96h
sample9 = 30ºC, 65RH, 48h
sample10 = 35ºC, 85RH, 48h
sample11 = 35ºC, 65RH, 96h
sample12 = 40ºC, 85RH, 96h
sample 13 = control

Table 4.6: Sensory properties of the gari samples

Sample/Run	Texture	Taste	Aroma	Colour	General acceptability
1	$7.70^{a,b}$	7.50^{b}	$6.80^{a,c,d}$	$7.30^{a,b,c}$	$7.10^{b,c,d}$
2	$7.50^{a,c}$	$7.80^{a,c}$	7.60^{a}	$7.80^{a,b}$	$7.60^{a,b}$
3	$7.60^{f,e}$	$7.40^{a,b}$	$7.00^{c,}$	$7.90^{a,b}$	$7.20^{c,}$
4	$7.70^{a,b}$	$8.00^{a,}$	$7.60^{a,}$	8.00^{a}	$7.60^{a,b}$
5	$5.70^{d,e}$	$5.80^{c,d}$	$5.70^{d,e}$	$6.10^{c,d}$	5.80^{e}
6	$6.10^{c,e}$	$6.00^{c,d}$	$5.60^{d,e}$	$6.60^{b,c,d}$	$6.50^{c,d,e}$
7	$7.50^{a,c}$	$7.60^{a,b}$	$7.30^{a,b}$	8.00^{a}	$7.50^{a,b}$
8	8.20^{a}	8.00^{a}	7.70^{a}	8.00^{a}	8.20^{a}
9	6.30^{eb}	$6.90^{a,b,c}$	$6.20^{b,c,d}$	$7.80^{a,b}$	$6.30^{d,e}$
10	$4.10^{f,g}$	5.40^{d}	$6.10^{b,c,d}$	5.80^{d}	5.90^{e}
11	$6.90^{a,d}$	7.80^{a}	$6.80^{a,b,c,d}$	$6.70^{a,b,d}$	$7.20^{b,c}$
12	$7.60^{a,b,c}$	$7.40^{a,b}$	$7.20^{a,b,c}$	$7.80^{a,b}$	$7.80^{a,b}$
13	$7.70^{a,b}$	$6.60^{b,c}$	$7.00^{a,b,c}$	$6.90^{a,b,c}$	$7.20^{b,c}$

a,b,c…. values on the same column with the same superscript are not significantly different ($p>0.05$)

sample1 = 30ºC, 65RH, 72h
sample2 = 40ºC, 65RH, 72h
sample3 = 30ºC, 85RH, 72h
sample4 = 40ºC, 85RH, 72h
sample5 = 30ºC, 75RH, 48h
sample6 = 40ºC, 75RH, 48h
sample7 = 30ºC, 75RH, 96h
sample8 = 40ºC, 75RH, 96h
sample9 = 30ºC, 65RH, 48h
sample10 = 35ºC, 85RH, 48h
sample11 = 35ºC, 65RH, 96h
sample12 = 40ºC, 85RH, 96h
sample13 = control.

4.2 DISCUSSION

4.2.1 pH of fermenting cassava mash as affected by temperature, relative humidity and time of fermentation.

Table 4.1 shows the pH values obtained during the fermentation of grated cassava mash for gari production. The values decreased with increase in fermentation time. The least pH was obtained in sample 12 (fermented at 40ºC, 85%RH and 96h) (4.52) although it was not significantly different ($p>0.05$) from samples (2,3,7,11 and control). Samples fermented for 96h had generally lower pH values while samples fermented for 48h had higher pH values. The significant decrease in pH of the cassava mash as fermentation time increased is supported by the findings of Achinwehu and Owuamanam (2001) who stated that the presence and activity of lactic acid bacteria hydrolyzed carbohydrates (notably starch) in the cassava into sugar, alcohols and organic acids. Thus, the produced organic acids led to the increase in the acidity of the mash and resultant decrease in pH. Also the result showed that fermentation temperature above 30ºC also may have created the necessary environment for the reduction in pH of the cassava mash. Probably the optimum temperature for the growth of the fermenting bacteria is above 30ºC. The values obtained at 96h were generally lower than the value obtained from the control (4.68). Thus the variables affected the pH of the fermenting mash.

4.2.2 TTA of fermenting cassava mash as affected by temperature, relative humidity and time of fermentation.

There was general increase in the titrable acidity of the samples of the fermenting mash with increasing fermentation time (Table 4.1). The highest TTA value was obtained in sample 12(fermented at 40°C, 85% and 96h) (0.85%) but did not differ significantly ($p>0.05$) from samples (7,8,11,12 and control).

Samples fermented for 96h had higher TTA values which differed significantly p>o.o5 from others, while samples fermented for 48h had lower TTA values. The increase in the titrable acidity could be attributed to production of lactic acid and other organic acids/ metabolites causing souring or acidification of the mash. Souring of the cassava mash during fermentation is an important and desirable attribute in the gari product. Acid production has been reported to be responsible for product stability, flavor development and cyanide elimination during cassava fermentation (Sefa- dedeh *et al*., 2004).

4.2.3 HCN of fermenting cassava mash as affected by temperature, relative humidity and time of fermentation.

Table 4.1 shows the HCN values obtained during the fermentation. The values significantly ($p>0.05$) decreased as fermentation time increased. The samples fermented for 96h had the least values with sample 12(fermented at 40°C, 85% RH and 96h) having the lowest value (42.8mg/kg) which differd significantly ($p>0.05$) from other samples fermented at 96h. The result obtained from this study showed that there was generally significant decrease in the HCN of all the samples at fermentation temperatures above 30°C which supported the

study by Owuamanam *et al* (2011). In their study on the effect of temperature of fermentation on gari quality, they found out that maintaining the temperature above the ambient, contributed to volatilization of residual cyanide, and also gave better performance in the physicochemical and sensory properties. Furthermore, the result suggested that the optimum temperature for fermentation in gari processing may be between 35-40^oC.

They stated that the optimum fermentation temperature enhances the cyanide reduction and the activities of microbes for the production of useful metabolites (Owuamanam *et al*, 2011).

However, the problem with consumption of cassava based products such as gari is the usually high level of HCN in the product (Bokanga, 1994; Ernesto *et al*., 2002). Some diseases are associated with the consumption of cassava products if inadequately processed (Cliff, 1994; Lambien *et* al., 2004). Thus, reduction in HCN level in these samples is of great significance. The result also showed that at 96h of fermentation, the values obtained were lower than the control (43.7mg/kg).

4.2.4 Proximate compositions of gari samples.

From the result of the proximate analysis of gari samples shown in table 4.2, it was observed that the moisture content of the samples ranged from (10.28%-12.79%). Sample 9 (fermented at 30^oC, 65%RH and 48h) recorded the lowest value (10.28%) while sample 4 (fermented at 40^oC, 85%RH and 72h) had the highest value (12.79%). The moisture content of the samples were within the range (6.34%-14.58%) specified by Codex Alimentarius Commission (1989). This suggests good storability for the gari samples. The

protein content of the gari samples ranged from 1.84% - 2.11% and the highest value for protein (2.11%) was obtained in sample 4 (fermented at 40ºC, 85%RH and 72h) while the least value (1.84%) was obtained in sample 6 (fermented at 40ºC, 75%RH and 48h). Majority of the values obtained were higher than that obtained from the control (1.88%) except sample 6(fermented at 40ºC, 75%RH, 48h) and 9 (fermented at 30ºC, 65% RH, 48h).

Thus there was improvement in the quality of the final product. For carbohydrate sample 4 (fermented at 40ºC, 85%RH and 72h) had the least value (81.06%) while sample 6(40ºC, 75%, 48h) had the highest value (83.76%). Sample 6 (fermented at 40ºC, 75RH and 48h) had the highest value for crude fibre (1.12%), while the least value (0.94) was obtained in sample 11 (fermented at 35ºC, 65RH and 96h). Sample 4(fermented at 40ºC, 85%RH and 72h) had the highest value (2.17%) for ash, while the least value (1.71%) was obtained in sample 5 (fermented at 30ºC, 75%RH and 48h).

4.2.5. Functional properties of gari samples.

The results of the functional properties of the gari samples are presented in Table 4.3. The ability to absorb water is a very important property of all flours and starches in food preparation. The range of water absorption capacity (3.50 -4.17g/g) observed for the gari samples showed that sample 4 (fermented at 40ºC, 85%RH and 72h) had the highest value (4.17g/g) , while sample 10 (fermented at 35ºC, 85%RH and 48h) had the lowest water absorption capacity (3.50g/g). The swelling index which is the ability of the starch to imbibe water and swell ranged from 3.36-3.62(ml/ml). Sample 4(fermented at 40ºC,

85%RH and 7 2h) had the highest value (3.62ml/ml) while sample 5(fermented at 30ºC, 75%RH, 48h) and 10(fermented at 35ºC, 85%RH, 48h) had the least value (3.36ml/ml). The result also revealed that sample 4(fermented at 40ºC, 85%RH and 72h) had the highest value for bulk density (0.50g/ml) while samples 5(fermented at 30ºC, 75%RH, 48h), 8(fermented at 40ºC, 75%RH, 96h) and 10(fermented at 35ºC, 85%RH, 48h) had the least value (0.47g/ml).

Ukpabi and Ndimele (1990) in their study reported that high bulk density increases the rate of dispersion which is important in the reconstitution of flours in hot water to produce dough. Thus sample 4(fermented at 40ºC, 85%RH and 72h) could be used for eba for its high swelling index and bulk density. The sample also had high crude protein content (2.11%).

4.2.6 pH, TTA and HCN of gari samples.

Table 4.4 shows the results obtained from the chemical properties of the gari samples. Sample 11(fermentd at 35ºC, 65%RH, 96h) had the highest value for total titrable acidity (0.47%) while sample 5(fermented 30ºC, 75%RH, 48h) had the least value (0.34%). During fermentation there was significant increase in the total titrable acidity of all the samples with increasing fermentation time (table 4.1).

This suggests that fermentation caused consistent increase in titrable acidity of the samples from 0h to 96h of fermentation. This increase could be attributed to the activity of the lactic acid bacteria during the fermentation process, which leads to the production of organic acids and other metabolites causing souring or acidification of the product. Sour taste is an

important and desirable quality attribute in gari production. Acid production has been reported to be responsible for product stability, flavor development and cyanide elimination during cassava fermentation (Okigbo, 1980).

However, after toasting the TTA values obtained from the samples were generally lower than those obtained during fermentation. The reduction could be due to the presence of volatile acids which evaporated during toasting due to temperature increase.

The result also revealed that sample 5(fermented at 30°C, 75%RH, 48h) and 10(fermented at 35°C, 85%RH, 48h) had the highest value for pH (5.85) while sample 8(fermented at 40°C, 75%RH, 96h) had the lowest value (5.60). The pH values were observed to decrease with increased fermentation time (Table 4.1). The decreasing values correspond with the production of acids by the fermentation organisms as suggested by Ahaotu *et al* (2011). However, after toasting the pH of the final product increased slightly probably due to the loss of some volatile organic acids during the toasting process. The result in table 4.4 also revealed that HCN content of the final gari samples reduced significantly when compared to the result in Table 4.1. The reduction is attributed to the toasting process. The HCN content of the gari samples ranged (4.11mg/kg – 7.86mg/kg) with sample 8(fermented at 40°C, 75%RH, 96h) having the lowest value (4.11mg/kg) and sample 10(fermented at 35°C, 85%RH, 48h) with the highest value (7.86mg/kg). Several workers have reported that significant amount of HCN is lost during the toasting process (Owuamanam *et al*., 2011; Irtwange and Achimba, 2009). It is also worthy of note that majority of the values were lower than that obtained from the control (5.18mg/kg). Infact samples 1(fermented at 30°C, 65% RH, 72h) and 11(fermented at 35°C, 65% RH, 96h)

which have been identified as the best samples for eba preparation and drinking (pasting properties) respectively have significantly lower HCN values as well as sample 4(fermented at 40ºC, 85% RH and 72h) .

4.2.7 . Pasting properties of gari samples.

The pasting properties of the samples are shown in table 4.5. Sample 11(fermented at 35ºC, 65% RH, 96h) had the highest peak viscosity (276.33cp). This was followed by sample 5(fermented at 30ºC, 75% RH, 48h) (273.08cp) while sample 3(fermented at 30ºC, 85% RH, 72h) had the least value (161.92cp). Peak viscosity indicates the water binding capacity of the starch grains and the ability of the starch to swell freely before their physical breakdown. It is an indication of the extent of starch damage or ease of cooking of the starch fraction in the gari (Balagoplan *et al*., 1988; Ikeagwu *et al*., 2010). Thus sample 11(fermented at 35ºC, 65% RH, 96h) could be said to have the best water binding capacity and its starch may be one of the easiest samples to cook (gelatinize).

The breakdown viscosity of the samples was variable with sample 12(fermented at 40ºC, 85% RH, 96h) having the highest value (94.25cp). Breakdown viscosity reflects the ability of the sample to withstand shear stress and heating during cooking. Thus, samples 3(fermented at 30ºC, 85% RH, 72h), 4(fermented at 40ºC, 85% RH and 72h), 10 (fermented at 35ºC, 85% RH, 48h) and control with values -61.35cp, -64.59cp, -57.22cp and -60.34cp respectively may not withstand cooking.

The highest final viscosity (377.17 cp) was obtained from sample 1(fermented at 30ºC, 65% RH, 72h) while the least value (227.33 cp) was obtained from sample

4(fermented at 40°C, 85RH and 72h). Final viscosity indicates the change in viscosity after the sample was held at 50°C. It shows the ability of the starch to form stable and viscous paste after cooking (Maziya-dixon *et al*., 2007). Gari is prepared for eating by stirring some quantity of gari granules in hot water to form a thick paste or gel (eba). The gel is moulded with the palm, dipped in soup or stew and swallowed (Achinewhu and Owuamanam, 2001).

The mouldability of the gel influences the consumer acceptability of the gari, which is directly related to the final viscosity of the paste. Thus sample 1(fermented at 30°C, 65% RH, 72h) can be taken as the best suited for this mode of consumption. Result obtained from the proximate composition of the final product indicates that the same sample1 had the crude protein and ash content values higher than the control (sample 13). Thus the process enhanced the product nutritionally.

Gari can also be taken as a snack by soaking in water and drinking it with roasted groundnut or dried fish. Sample 11(fermented at 35°C, 65% RH, 96h) which had the highest value for peak viscosity (276.33cp) could be said to be best suited for drinking. The results obtained in the study therefore indicate that different fermentation conditions are required for producing gari that could be used for different purposes, may be for eating with soup or stew, or for drinking.

Samples 3(fermented at 30°C, 85% RH, 72h), 4(fermented at 40°C, 85%RH and 72h), 10(fermented at 35°C, 85% RH, 48h) and 13(control) had the least values for setback viscosity (71.00cp, 62.41cp, 71.12cp and 61.15cp respectively). Set back viscosity of starch paste is an indication of resistance of the starch to retrograde (Sanni *et al*., 2001).

Peak time and pasting temperature correspond to gelatinization time and temperature. It is the time and temperature required for the gari to form a thick paste. Thus sample 10 had the least time (4.36min) while sample 1 had the least pasting temperature (80.12^{o}C).

The results from the study are of significance since they could be used as a guide for quality index of gari meant for different uses.

4.2.8. Sensory properties of gari samples.

The results of sensory evaluation of the final products are presented in Table 4.6.

Texture is an important attribute which influences level of acceptability in eba. From Table 4.6 the statistical analysis shows that the evaluated samples differed significantly ($p<0.05$) in terms of texture. The highest texture score was observed in sample 8(fermented at 40°C, 75% RH, 96h) (8.20) while sample 10(fermented at 35°C, 85% RH, 48h) had the least score (4.10). The value obtained from sample 1(fermented at 30°C, 65% RH, 72h) however was not significantly different from the highest value, still indicating that sample 1 could be the best for eba. For the taste attribute samples 4(fermented at 40°C, 85%RH and 72h) (8.0) and 2(fermented at 40°C, 65%RH, 72h) (8.0) were preferred most while samples 5(fermented at 30°C, 75%RH, 48h) (5.8) and 10(35°C, 85%, 48h) (5.4) were least preferred. For aroma, samples 2(fermented at 40°C, 65%RH, 72h) (8.0) and 4(fermented at 40°C, 85%RH and 72h) (7.6) were best preferred while sample 6(fermented at40^{o}C, 75%RH, 48h) (5.6) was least preferred.

In terms of colour samples 4(fermented at 40°C, 85%RH and 72h) and 8(40°C, 75%RH, 96h) (8.20) were best preferred while sample 10(35°C, 85%, 48h) was least preferred. For taste and colour, it was observed that majority of the average scores by panelists were higher than the control (6.60) and (6.90) respectively thus showing that combination of the fermentation variables improved the final products sensitivity. In the overall, sample 4 was well accepted by panelists.

CHAPTER FIVE

CONCLUSION / RECOMMENDATION

5.1 Conclusion

The study revealed that the conditions for the fermentation of sample 4 (temperature 40ºC, relative humidity 85% and time 72h) produced gari with relatively high crude protein content, ash, swelling index and water absorption capacity. Statistical analysis showed that the values obtained for these parameters were significantly different ($p<0.05$) from the values obtained from the other samples. This still buttress the fact that sample 4 may be the best product in terms of the nutritional quality and mouldability for swallow during eating. Although it did not produce a product with the least HCN content after toasting, the value obtained (4.77mg/kg) was very low and it did not differ significantly ($p>0.05$) with the least HCN value (4.31mg/kg).

However, the result of the pasting properties revealed that sample 1(fermented at 30ºC, 65%RH, 72h) had the best properties for mouldability whose HCN content was found to be lower than that of sample 4, and the nutritional quality comparable to sample 4 fermented at (temperature 40ºC, relative humidity 85% and time 72h).

A critical look on the results also indicated that the length of fermentation may have had the most significant effect on most of the parameters monitored. Samples fermented for 96h had least values for HCN. The least pH values were also obtained in 96h fermented samples. Although samples fermented for 72h had the highest values in terms of protein, ash, water absorption capacity and swelling index.

Sensory results also showed that the product was well accepted by the panelists.

5.2 Recommendation

In this direction of study, other works should be carried out on the effect of other variables such as innoculation of cassava mash with preferment liquor under controlled conditions of fermentation (temperature, relative humidity and time) so as to further enhance gari processing.

5.3 Contribution of work to knowledge

The contributions of this work to knowledge are as follows;

By varying the fermentation conditions, HCN content of these samples;

sample1 fermented at (30^oC, 65RH, 72h)
sample2 fermented at (40^oC, 65RH, 72h)
sample3 fermented at (30^oC, 85RH, 72h)
sample4 fermented at (40^oC, 85RH, 72h)
sample7 fermented at (30^oC, 75RH, 96h)
sample8 fermented at (40^oC, 75RH, 96h)
sample11 fermented at (35^oC, 65RH, 96h)
sample12 fermented at (40^oC, 85RH, 96h)

reduced below the control sample which was produced using the traditional method.

Thus the nutritional quality of the products was significantly improved.

Also the different fermentation conditions used in this research are required for producing gari that could be used for different purposes thus, sample 1 fermented at (30^oC, 65% RH, 72h) can be taken as the best suited for eba while sample 11 fermented at (35^oC, 65RH, 96h) can be taken as the best for drinking.

REFERENCES

Achinewhu, S.C. and Owuamanam, C.I. (2001). Garrification of five improved cassava cultivars, physicochemical and sensory properties of garri yield. *African Journal of Root Tuber Crops*. **4**: 18-21.

Ahaotu, I., Ogueke, C.C., Owuamanam, C.I., Ahaotu, N.N. and Nwosu, J.N. (2011). Protein improvement in gari by the use of pure cultures of microorganisms involved in the natural fermentation process. Pakistan Journal of Biological Sciences. 14 (20): 933 – 938

Almazan, A.M. (1988). Influence of sugar and cyanide concentrations on fried cassava chip quality. *Journal of Science Food and Agriculture*. **42**: 6-12.

AOAC (1990). Association of Official Analytical Chemists. 15th Edition, AOAC. Inc. Arlington, V.A.U.S.A, pp1945-1962.

Awan, J.A. and Okaka, J. C. (1983). Elements of food spoilage and preservation (4th ed.) Institution of Management and Technology, Enugu, Nigeria pp 187-188.

Azam-Ali, S.E., Fellows, P and Battock, M. (2003). Small-scale food processing. A directory of equipment and methods. Second edition. ITDG Publishing. pp 256.

Bainbridge, Z., Tomlins, K. and Westby, K. (1996). Method of assessing quality characteristics of non-grained starch staples. Natural Resource Institute, Chattam UK. pp 3.

Balagoplan, C., Dadmaja, G., Nanda, S. K. and Moorthy, S. N. (1988). Cassava in food, feed and industry. CRC Press, Boca Raton. pp 240 – 301.

Bencini, M.C. (1991). Post-harvest and processing technologies of African staple foods: A technical compendium. Agricultural service bulletin No 89, FAO Rome pp 174-192.

Bokanga, M. (1994). Distribution of cyanogenic potential in cassava germplasm: In Processing Workshop on Cassava Safety (Bokanga, M., Esser, A.J.A., Poulter, N., Rosling, H., and Tewe, O. eds) 1-4th March, Ibadan, Nigeria, Acta.Holt. **375**: 117-123.

Brinsima, D.H., Witsenberg, W.W. and Wurden, W. (1983). Selection of technology for food processing in developing countries. Publishers of international course in food science and nutrition. Centre of Agriculture and documentation, Wageningen, the Netherlands.

Cock, J.H. (1985). Cassava: a new potential for neglected crop IADS development-oriented literature series. West view press, Corlondo. pp 104-110

Codex Alimentarius Commission (1989). Codex standard for edible cassava flour. Codex Standard 176-1989, revision 1995.

Cordoso A., Ernesto M., Nicala D., Mirrone E., Charvane L. and N'zwalo H. (2004). Combination of cassava flour cyanide and urinary thiocyanate measurement of school children in Mozambique. *Int. J . Food Sci.Nutr.* **55**:183-190.

Collard, P. & Levis, S. (1959). A two stage fermentation of cassava. Nature. 183: 620-621.

Delange F., Ekpechi L.O. and Rosling H. (1994). Cassava cyonogenesis and iodine deficiency disordes. *Acta Hortic* **375**:289-293.

Dulcer N., Humberts M., Cliff J., Anorld C. and Howard B. (2008). Rising African cassava production, diseases due to the cyanide intake and control measures. *J Sci Food Agric* **88**:2043-2049.

Ernesto, M., Cardoso, A.P., Cliff, J and Bradbury, J.H. (2002). Cyanogens in cassava flour and roots and urinary thiocyanate concentration in Mozambique. *Journal of Food Composition Analyses*, **13**: 1-12.

FAO (2006). Food and Agriculture Organization , Year Book, FAO. Rome, pp: 13-17.

Fapojuwo, O.E. (2008). Determinants of food security among women cassava processors in Ogun State Nigeria. Proceedings of 32nd Annual Conference Nigeria Institute of Food Science and Technology, Oct. 13th-17th. pp: 284-285.

Flach, M. (1990). Garri processing in North West province of Cameroun. Working document No 5 FAO project.

Hahn, S.K, and J. Keyser. 1985. Cassava: a basic food of Africa. Outlook on Agriculture 4: 95-100.

Hahn, S.K., N.M. Mahungu, J.A Otoo, M.A M. Msabaha, N.B. Lutaladio, and M.T. Dahniya. 1987. Cassava and African food crisis. Pages 24-29 in Tropical root crops -root crops and the African food crisis. Proceedings, Third Triennial Symposium of the International Society for tropical Root Crops - Africa Branch, edited by E.R Terry, M. Akoroda, and O. B. Arene. 17-23 August 1986, Owerri, Nigeria

Ikeagwu, O. J., Okechukwu, P. E. and Ekumankana, E. O. (2010). Physico chemical and pasting characteristics of flour and starch from Achi (*Brachystegia eurycoma*) seed. *Journal of Food Technology.* **8**(2): 58 – 66.

Irtwange, S.V. and Achimba, O. (2009). Effect of the duration of fermentation on the quality of garri. *Journal of Biological Sciences.* **1**(3): 150-154.

Lawson, J.S. and Madrigal, J.L. (1994). Robust design through optimization techniques. Quality Engineering **6**: 593-608.

Maziya-Dixon, B., Dixon, A. G. O. and Adebowale, A. A. (2007). Targeting different uses of cassava: genotypic variations for cyanogenic potentials and pasting properties. International Journal of Food Science and Technology. 42(8): 969 – 976.

Moorthy, S.N. (1983). Cassava starch and its modification, Technical bulletin, Central Tuber Crops Research Institution and Trivandrum, India, pp 32.

.

Norman, N.P. and Joseph, H.H. (1995). Food science, 5th Edition. Chapman and Hall, New York.

Nweke, F.I., Spenser, D.S.C. and Lynam, J.K. (2002). The Cassava Transformation Africans best kept secret. Michigan State University Press, USA. pp:7-206.

Obilie, E. M., Tano-Debrah, K., Amoa-Awua, W. K. (2004). Souring and breakdown of cyanogenic glucoside during the processing of cassava into atieke. *International Journal of Food Microbiology.* **93**: 115-121.

O'Brien, G. M., Taylor, A. J. and Poulter, N. H. (1991). Improved enzymic assay for cyanogens in fresh and processed cassava. *Journal of Science of Food and Agriculture.* **56**: 277-289.

Ogueke, C.C., Ehirim, C., Owuamanam, C.I., Ahaotu, I. and Olawuni, I.A. (2013). Quality characteristics and HCN in gari as affected by fermentation variables. *International Journal of Life Sciences.* 2: 21-28.

Okafor, N. and Ejiofor, M. (1990). Rapid detoxification of cassava mash fermenting for gari production following inoculation with yeast simultaneously producing linamarase and amylase. Proc. Biochemistry. 25:82-86.

Okaka, J.C. (2001). Food composition, spoilage and shelf life extension. Oganco Academic Publishers. pp 233-234.

Okaka, J.C. (2005). Tropical perishable plant, handling, processing and storage. Silicon publishers, Enugu. Pp 182-183.

Oluwole A., Onabolu A., Rosling H., Pearson A and Link H, (2003). Incidence of endermic ataxic polyneuropathy and its relation to exposure to cyanide in Nigerian community. *J Neuro Neurosurg Psychol* **74**:1417-1422.

Oni, O. K., Gernah, D. I. And Ibrahim, J. S. (2008). Effect of different particle sizes on the functional and sensory properties of soy gari. Proceedings of 32nd annual conference of Nigerian Institute of Food Science and Technology, October 13 – 17. pp284 – 285.

Onyenuga, V.A. (1985). Nutrient content of gari in Nigeria. Food and feeding stuff, their chemistry and nutritive value (3rd ed). Ibadan university press. pp 20-27.

Owuamanam, C.I., Iwouno, J.O., Ihediohanma, L.I. and Barber, L.I. (2010). Nutritional evaluation of gari diets from varying fermentation time using animal model. *Researcher*. **2**(8).

Owuamanam, C.I., Ogueke, C.C., Achinewu, S.C. & Barimala, I.S. (2011). Quality characteristics of garri as affected by pre-ferment liquor, temperature and duration of fermentation. *American Journal of Food Technology* .**6**: 374-384.

Oyewole, O.B., 2001. Characteristics and significance of yeast involvement in cassava fermentation for fufu production. Int. *J. Food Microbiol*. 65: 213-218.|

Sani, L.O., Ikumola, D.P. and Sani, S.A. (2001). Effect of length of fermentation and varieties on the qualities of sweet potato-gari. Proc. 8th triennial symposium of the International Society for Root Crops, African Branch (ISTR-AB), Ed. M.O. Akoroda, IITA, Ibadan, Nigeria. 12-16 November 2001, pp 208-211.

Sanni, L.O. (2005). Cassava utilization and regulatory framework in Nigeria: A report. United Nations Development Organization (UNIDO). pp: 62.

Sefa-Dedeh, S.,Cornelius, B., Amoa-Awua, W., Sakyi-Dawsa, E.O and Afoakwa, E. (2004). The microflora of fermented corn. *International Journal of Food Microbiology*.96(1), pp 97-102.

Sirtunga D., Aris D.and Sayre R.T. (2004). Over expression of hydroxynitrite lyase in cassava roots accelerates cyanogenesis and detoxification. *Plant Biotechnology J.* **2**:37-43.

Sokari ,T.G. and Karibo, P.S. (1992). Changes in cassava toxicity during processing into garri and ijapu, two fermented food products. Food Additive Contaminants. 9:379-384.

Sunderesan, S., Nambisan, B. and Easwari, C.S. (1987). Bitterness in cassava in relation to cyano-glucoside content. *Indian Journal of Agricultural Science.* 57: 34-40.

Ukpabi, U.J. and Ndimele, C. (1990). Evaluation of garri production in Imo State Nigeria. *Nigerian Food Journal.* **8**: 105-110.

Vasconcelos, A.T., Twiddy, D.R., Westby, A. and Reilly, P.J.A. (1990). Detoxification of cassava during preparation. *International Journal of Food Science and Technology*. **25**: 198-203

Watt, B.M., Ylimaki, G.L., Jeffery, L.E. and Elias, L.G. (1985). Basic sensory methods for food evaluation. IDRC-277e:pp 66-67.

Westby, A. and Twidy, D.R. (1992). Characteristics of gari and fufu preparation procedures in Nigeria. *World Journal of Microbiology and Biotechnology*. **8**, 175-185.

APENDIX

pH

samples	1st	2nd
1	5.02	5.02
2	4.51	4.91
3	4.72	4.72
4	4.8	4.88
5	5.4	5.5
6	5.4	5.56
7	4.6	4.64
8	4.6	4.7
9	5.3	5.42
10	5.43	5.43
11	4.6	4.6
12	4.5	4.54
control	4.6	4.76

LSD
0.214033389

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Row 1	2	10.04	5.02	0
Row 2	2	9.42	4.71	0.08
Row 3	2	9.44	4.72	0
Row 4	2	9.68	4.84	0.0032
Row 5	2	10.9	5.45	0.005
Row 6	2	10.96	5.48	0.0128
Row 7	2	9.24	4.62	0.0008
Row 8	2	9.3	4.65	0.005
Row 9	2	10.72	5.36	0.0072
Row 10	2	10.86	5.43	0
Row 11	2	9.2	4.6	0
Row 12	2	9.04	4.52	0.0008
Row 13	2	9.36	4.68	0.0128

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	3.260984615	12	0.271748718	27.68599791	2.85668E-07	2.603660748
Within Groups	0.1276	13	0.009815385			

Total	3.388584615	25				

TTA

samples	1st	2nd
1	0.81	0.81
2	0.7	0.82
3	0.7	0.74
4	0.68	0.7
5	0.63	0.63
6	0.6	0.66
7	0.8	0.82
8	0.86	0.8
9	0.68	0.68
10	0.6	0.66
11	0.8	0.8
12	0.82	0.88
control	0.79	0.79

LSD
0.074837366

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Row 1	2	1.62	0.81	0
Row 2	2	1.52	0.76	0.0072
Row 3	2	1.44	0.72	0.0008
Row 4	2	1.38	0.69	0.0002
Row 5	2	1.26	0.63	0
Row 6	2	1.26	0.63	0.0018
Row 7	2	1.62	0.81	0.0002
Row 8	2	1.66	0.83	0.0018
Row 9	2	1.36	0.68	0
Row 10	2	1.26	0.63	0.0018
Row 11	2	1.6	0.8	0
Row 12	2	1.7	0.85	0.0018
Row 13	2	1.58	0.79	0

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*

Between Groups	0.158584615	12	0.013215385	11.01282051	6.29177E-05	2.603660748
Within Groups	0.0156	13	0.0012			
Total	0.174184615	25				

HCN

samples	1st	2nd
1	47	47
2	48.8	49
3	46.6	47
4	46.9	46.9
5	53.7	53.9
6	55	55.2
7	43.8	43.8
8	43.4	43.8
9	51.9	51.9
10	54.2	54
11	43	43.4
12	42.4	43.2
control	44	44

LSD
0.479342767

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Row 1	2	94	47	0
Row 2	2	97.8	48.9	0.02
Row 3	2	93.6	46.8	0.08
Row 4	2	93.8	46.9	0
Row 5	2	107.6	53.8	0.02
Row 6	2	110.2	55.1	0.02
Row 7	2	87.6	43.8	0
Row 8	2	87.2	43.6	0.08
Row 9	2	103.8	51.9	0
Row 10	2	108.2	54.1	0.02
Row 11	2	86.4	43.2	0.08
Row 12	2	85.6	42.8	0.32
Row 13	2	88	44	0

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	487.3415385	12	40.61179487	824.9270833	1.11683E-16	2.603660748
Within Groups	0.64	13	0.049230769			
Total	487.9815385	25				