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COLLEGE OF SCIENCE

DEPARTMENT OF FOOD SCIENCE AND TECHNOLOGY

INFLUENCE OF BAKING TIME ON SENSORY PROPERTIES AND SHELF LIFE OF BREAD FROM COMPOSITE CASSAVA WHEAT FLOUR (CCWF)

BY

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(BSc. BIOCHEMISTRY (PG7048416))

JUNE, 2018

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OF BREAD FROM COMPOSITE CASSAVA WHEAT FLOUR (CCWF)

A THESIS SUBMITTED TO THE DEPARTMENT OF FOOD SCIENCE AND TECHNOLOGY IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF SCIENCE IN FOOD QUALITY MANAGEMENT

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DECLARATION

I hereby declare that this submission is my own work towards the Master of Science in Food Quality Management and that, to the best of my knowledge, it contains no material previously published by another person nor material which has been accepted for the award of any other degree of the University, except where due acknowledgement has been made in the text.

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ABSTRACT

The effect of variation in baking time on the sensory characteristics and shelf life of composite cassava wheat flour bread has been studied. A 12% substitution of wheat flour using high quality cassava flour (*Manihot esculenta*) made from the ―Bankye Hema‖ variety was used in the study. A complete randomised design was used for the study and three treatments namely baking time of 20 min, 25 min and 30 min were applied. Four sensory parameters were analysed by 25 panellist using a 9-point hedonic scale. The parameters accessed were taste, texture, aroma and overall preference. The results of the analysis showed that the control sample (100% wheat bread) was most preferred followed by the composite cassava wheat bread baked for 25 min. However, the taste results of the composite cassava wheat bread baked for 20 min was not significantly different ($p > 0.05$) from the control (100% wheat bread) The results from the shelf life study showed that the composite cassava wheat flour bread had less counts as compared to 100% wheat flour bread after 120 h of storage. Thus, bread made from composite cassava wheat flour bread could stay longer than regular wheat flour bread. It can be concluded from the study that variation of baking time on composite cassava wheat flour bread (12:88) (w/w) influenced the sensory attributes of the bread. The 100% wheat flour bread baked at 179℃ for 25 min was the most preferred by consumers, whiles the composite cassava wheat flour bread (12:88) (w/w) had a longer shelf life compared to 100% wheat flour bread. The findings from the study highlights the impact of varying baking time on the sensory properties of composite cassava wheat flour bread.

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LIST OF ABBREVIATIONS

ANOVA	-	Analysis of Variance
CCWF	–	Composite cassava wheat flour CFU - Colony forming units
CSIR	–	Centre for Scientific and Industrial Research FAO - Food and Agriculture Organization
FRI	–	Food Research Institute HQCF – High Quality Cassava Flour TPC – Total plate count
TAC	-	Total Aerobic count PDA - Potato dextrose agar
USAID	-	United States Agency for International Development

ACKNOWLEDGEMENTS

My first acknowledgement goes to the God who grace, and mercies have brought me this far

My sincere gratitude goes to my supervisor, Dr. Leonard de-Souza for his encouragement and consistent direction during this study.

A very special appreciation goes to Ransford Nyarko and Staff of Flame bakery for their assistance in the baking of bread for this project. May the Lord reward your labour.

DEDICATION

This thesis is dedicated to my Wife , Mrs Abere Nyarko and my brother Ransford Nyarko

CHAPTER ONE

INTRODUCTION

1.1 Background

Bread has been a dietary staple for many communities across the centuries, Bread making goes back to the era in history when development of civilization was commenced. Historically at about 8000 BC the grinding stone was used in Egypt to grind grains including wheat (Rosell, 2011). Modern breads such as the chapattis and tortillas from India and Mexico respectively, resemble the breads produced in that era. From 5000 to 3700 BC bread became a staple food and was exported to other cultures from Egypt during cross continental trade along the Nile (Rosell, 2011).

In the medieval era, bread was not only used as food, but was also used as an absorbent plate during dinning. It was common place to find at a table setting bread 4 to 6 inches long being used as an absorbent plate (Rosell, 2011). It was not until the 15th century that wood was made to replace bread being used as an absorbent plate (Rosell, 2011). In the 19th century, bread was often adulterated with harmful ingredients such as chalk, alum and ammonium carbonate, leading to governmental policies such as the food adulteration act in Britain (Delwin, 1997).

In modern day key innovations of the industrial revolution such as improved milling, cheaper energy sources for baking has made bread more common place with increasing demand and an increase in volume of production. The baking industry in Germany were the first to bake bread commercially using yeast, thus influencing consistency in taste and visual appeal of bread (Rosell, 2011). Currently artificial preservatives, emulsifiers, and other chemical additives are being used to improve dough and soften texture of baked bread and to improve the shelf life of mass-produced breads. The shelf life of bread is usually between 2 -5 days (Smith *et al*., 2004). Thus, the art of bread making though an old skill has steadily progressed through the ages. Each step in the process from selection and preparation of the ingredients and actual processing such as the mixing and baking of the loaf is controlled.

In bread making, common ingredients used are flour (usually wheat flour), salt, yeast and water. Additionally, other ingredients such as artificial colorants and flavours maybe included in the recipe to change colour, texture, appearance and shelf life of the bread. Milk may be used in combination with water to alter the texture of the bread. In some European countries ingredients such as cheese and herbs and sweet ingredients such as dried fruits pieces can be added for greater bread variety and better consumer appeal (Rosell, 2011).

Composite flours using a combination of wheat flours, with other flours such as cassava, sorghum, millet or maize in different proportions can be employed to produce a range of different breads (Dhingra and Sudesh, 2004). It is recommended that at least 70% wheat flour must be used in leavened breads to obtain a good rise during proofing of bread (Eriksson, 2013).

Unleavened breads are made from the same ingredients and principles as described above however without yeast yielding a dough that when baked produces crisp flat bread, examples being chapattis, matzos and tortillas (Eriksson, 2013).

The characteristics of bread are influenced by ingredients used and the baking process employed. The quality of bread is impacted by the quality of ingredients (Rosell, 2011).

Thus, ingredient selection in making of bread is very pivotal to achieve expected quality of the final product. The various ingredients used in making bread are as follows;

i. Yeast

Yeasts are living micro-organisms that are used to make the dough rise through the production of carbon dioxide. With optimal conditions, the yeast starts to grow fermenting the dough in the process. During the fermentation process, sugars are converted to alcohol, water and carbon dioxide. Yeast is mainly available as dried yeast and must be reconstituted in warm water before use. The yeast most commonly used is Saccharomyces cerevisiae (Rosell, 2011).

ii. Salt

Generally, salt used in baking should be free from impurities and foreign matter. Salt has the following functions when used in bread dough preparation:

- reduces spoilage
- helps to strengthen the gluten structure • helps to regulate the rate of fermentation.
- Moisture retention.

Salt can easily damage yeast cell walls and hence must not be allowed to come into contact with yeast during storage (Rosell, 2011).

iii. Sugar

Sugar used should be clean and pure of impurities. Normally the flour has enough natural sugar (about 2.5-3%) for the fermentation. However, depending on the recipe, sugar can be added to produce breads such as sugar bread (Rosell, 2011).

iv. Fats

Fats used in baking include butter and margarine. The quantity of fat used depends on the bread recipe and consumer expectation. Generally, up to 1% of the flour weight of fat is used. Fat used improves the keeping quality and softness of the loaf. Excessive use of fat can affect the efficiency of the fermentation process. (Rosell, 2011).

v. Baking powder

Baking powder comprises of bicarbonate and a weak acid. Baking powder releases carbon dioxide gas through an acid-base reaction into the dough, producing bubbles in dough to expand and thus leavening the mixture (Rosell, 2011).

vi. Flour

Flour is obtained from grinding dry grains mainly cereals to obtain a powder. Flour is a source of starch and protein for baked bread providing structure to the bread. The amount of protein in the flour impacts on the quality of bread produced (Rosell, 2011).

Wheat flour, contains the following proteins albumin, globulin, and proteases which are water soluble and glutenin and gliadin which are water-insoluble. Glutenin forms chainlike strands when the flour is mixed with water whiles the gliadin forms cross links between the chains of glutenin producing a network of strands. This network of strands is called gluten and is responsible for characteristics such as texture of bread. During storage, flour should not be exposed to high temperatures and humidity (> 60 %humidity). Flour can be kept in the afore mentioned conditions for up to 6 months (Rosell, 2011).

The bread industry in Ghana is similar to global trends in bread making, however majority of bread is baked by small scale industries. The main types of bread consumed in Ghana are sugar bread, butter bread and brown bread. These types of bread are made using wheat flour as flour for dough.

According to Antwi-Bediako(2008) an estimated Ghc 1,059 million is spent annually on bread. The highest budget for food in Ghanaian households in all localities in Ghana is allocated to bread and Cereals, about 20% (Antwi-Bediako, 2008), the high consumption of bread in Ghana implies that a lot of forex is required to import wheat flour as wheat is not grown locally due to climatic conditions. Several options have been explored in the substitution of wheat partially with local ingredients. An example of such local substitutes is the use of high quality cassava flour (HQCF). Studies have explored the use of HQCF and wheat composite flour with varying percentages of substitution of wheat flour with HQCF forming a composite flour (also known as composite cassava and wheat flour (CCWF)) from 10% -20% HQCF (Amegashie, 2004). Further work has been done on processing parameters such as varying baking temperature and time of the composite cassava and wheat flour (CCWF) during baking (Shittu *et al*, 2007). These studies have been aimed at promoting the use of HQCF in bread production.

1.2 Problem statement

The baking industry in Ghana is heavily dependent on wheat imports for bread production. Between September 2016 and March 2017, the price of wheat on the world commodity market increased by 18.82% (USDA Foreign Agricultural Service, 2014). The excessive cost of wheat flour and increasing demand of bakery products are among the factors that cause huge import bills of many African countries including Ghana. Research has shown that up to 20% of wheat flour can be replaced with other types of flour for composite flour bread making without much change in the sensory attributes (Nwanekezi, 2013). Exploring the use of local ingredients such as cassava flour in the partial replacement of wheat flour in bread production has economically significant potential, as bread is widely consumed daily in most households.

Despite the scientific evidence of feasibility of using cassava flour as partial substitute and the ready availability of cassava, most bakeries continue to use 100% wheat flour for their products. Making the use of cassava flour less competitive when compared to wheat flour. Bread made from composite cassava wheat flour may be more patronized by majority of bakeries in Ghana if consumer acceptability is high similar to bread made solely from wheat flour. Additionally, another incentive will be performance of bread with regards to freshness, which is linked to the shelf life of the bread, thus how long can the bread be kept within the supply chain from bakery to consumer, before spoilage. Hence if bread made from composite cassava wheat flour has a longer shelf life, this would encourage the use of HQCF in the production of CCWF bread.

Replacement of wheat flour by HQCF in bread making is economically significant in Ghana as wheat is mainly imported from Canada, Argentina and the EU. Ghana's wheat imports is estimated at 700,000 tonnes for 2017-18, a 5.4% increase from imports in 2016-17 (Schroeder, 2018). The per capita consumption of wheat in Ghana is 20kg/year (Schroeder, 2018). It is estimated that 80% of wheat flour is used for bread making, and the remaining 20% is used in other bakery products (Schroeder, 2018).

Hence there is the need to improve the quality of CCWF bread, hence the impact of varying baking time on consumer acceptability and shelf life of bread from CCWF needs to be intensified.

1.3 The Objectives of the Study

The study aims at investigating the influence of varying baking time on sensory attributes and shelf life of bread from composite cassava wheat flour CCWF (12% High Quality Cassava flour (HQCF): 88% wheat flour, respectively). Research has indicated that from 5%20% of wheat flour can be substituted in bread making without adverse effect on bread quality (Ciacco and D'Appolonia, 2007)

1.3.1 Specific Objectives

The specific objectives of this work are:

1. Determine the effect of baking time on sensory attributes (Taste, texture, aroma and overall preference) of CCWF bread.
2. Determine the correlation between baking time and shelf life of composite cassava and wheat flour bread.

1.4 Significance of Study

Investigating the effect of baking time on the sensory characteristics and shelf life of CCWF bread will improve the quality and competitive advantage of CCWF bread over bread from 100% wheat flour. Thus, promoting the use of HQCF as a substitute for wheat flour. With increases in global wheat prices, the use of HQCF should be promoted as a substitute to wheat in terms of price competitiveness. Although other factors such as increase in local wheat milling capacities and cheaper wheat varieties may impact the price competitiveness of HQCF, the advantage of value addition and job creation along the supply chain far outweighs the use of 100% wheat flour.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

2.1 Types of Bread

Bread is the product obtained from the baking of dough. Dough could be classified as leaven or unleavened depending on whether yeast is used or not. The dough is obtained from mixing water, flour, margarine or butter and other optional ingredients (Treuille and Ferrigno, 2008). Globally there are different types of bread, that have evolved over the years as per the culture and cuisine preference of various communities around the world. A summary of the various bread types are indicated in Table 1;

Table 1a, Types of Bread

Name	Description
Ah Merahrah	Baked from fenugreek seeds and maize; the resultant dough before baking is fermented and flattened.
Ajdov Kruh	Baked using composite flour of buckwheat and potato.
Anadama bread	Baked using a composite flour of cornmeal and molasses.
Anpan	Bread made from red bean paste
Appam "Hoppers"	Baked from fermented white flour
Arepa	Bread is made from ground corn flour
Baba	Thick bread with sweet filling
Bagel	Circularly shaped with sesame toppings
Baguette *French stick, French bread*	Thin long bread commonly found in French speaking countries.
Balep korkun	Flat bread made from barley flour fried in a pan.
Barbari bread	Common in Iran and Afghanistan
Barmbrack	Similar to cake bread but sweeter, filled with raisons
Bastone *Italian stick, cane, staff*	Long in form but thicker than baguette
Bhakri	Made from maize flour, with high fiber content
Bialy	Circularly shaped but filled in butter.
Bing	Thicker than Mexican tortilla.

Source

Blaa	White dough bread usually baked in the form of a bun
Bread roll	Round short bread served with butter

(Treuille and Ferrigno, 2008)

Table 1b, Types of Bread

Breadstick	Used as an appetizer and comes in the form of a stick
Brioche	Made from a large content of eggs and butter, mainly served as deserts.
Broa	Made from composite flour, mainly of wheat and rye flour
Brown bread	Made from Rye or wheat flour, high in fibre
Bun	Sweet bread used in the preparation of sandwich
Canadian White	White, thick sandwich bread, that originated from Canada
Carrot bread	Baked with wheat flour with grated carrot pieces.
Česnica	Baked normally as a tradition in Europe with an actual silver coin placed in the middle of the bread.
Challah	Made from wheat flour, egg and olive oil. This bread originated from Isreal and commonly prepared by the Jews.
Chapati	Flat bread cooked without bread, originated from India
Crêpe	Thin pancakes, that are usually served as part of breakfast with the various option of filling.
Crisp bread	Made from dry rye flour using flour salt and water.
Crumpet	Circular flat bread with
Cuban bread	Originating from Cuba, the method of preparation and baking is similar to French bread.
Curry bread	This is made of Curry wrapped with flat bread that is deep fried or baked.
Damper	Baked from What flour. This type of bread is common in Australia.
English muffin	Round bread consumed as an accompaniment, originating from UK
Farl	Dough is spread on a griddle, divided into 4 equal sections and cooked.
Filone	In terms of appearance and preparation identical to French barquette
Flatbread	Usually circular and thin in width
Flatbrød	A traditional bread common in Norway that is eaten with soups
Flatkaka	Round, thin and dark bread usually fried
Focaccia	Baked in a similar manner to pizza, flat and round originating from Italy
Fougasse	Popular bread in France usually shaped in the form of an ear of wheat
Green onion pancake	Thin flat bread made from dough, filled with green onions, normally served as a side dish in Chinese cuisines.
Khakhra	Similar to chapati but dryer and much crispier

Source

Khubz	Originating from the middle east, this small size flat made from wheat flour
Kifli	Originating from Europe, this bread contains yeast and is usually shaped in the form of a crescent.
Kisra	Originating from southern Sudan, Kisra is made from fermented wheat dough.

(Treuille and Ferrigno, 2008)

Table 1c, Types of Bread

Kulcha	Flat bread with a small amount of yeast and spices originating from Northern India
Lagana	Baked on the first day in lent, this flat bread originated from Greece
Lahoh	Bread in the form of a pancake with a spongy texture commonly eaten by the people of Djibouti and Yemen
Laobing	Similar to Chapatti, laobing originated from the northern part of china. This is sometimes called the Chinese pan cake
Lavash	Lavash is a thin flatbread common in Iran Turkey and Azerbaijan
Lefse	Baked from flour and potatoes common in Norway
Malooga	Flat bread commonly found in Yemen, eaten alongside beans and other dishes.
Mantou	Sweet steamed bread, popular in the northern part of China
Markook	Very thin flat wheat flour bread
Marraqueta	Very popular in Chile, it's a bread bun with a crispy crunchy texture.
Massa Sovada	Portuguese bread sweetened with milk and sugar and baked on special occasions.
Matzo	Flatbread commonly found in Israel and made during special celebrations in the Jewish occasions
Melonpan	Made of enriched dough covered in thin layer of crispy cookie dough.
Miche	Sweet Japanese bread made from flour and cookie dough
Michetta	Italian bread bulged in the middle
Mollete	White bread served with oil
Montreal-style bagel	A sweet bread with a hole in the middle with ingredients being mainly honey and eggs.
Naan	Leavened flat bread baked in the oven, common in the middle east.
Ngome	Flat bread from Millet flour. Common in Mali
Obwarzanek krakowski	The bread dough is braided together, boiled before baking
Pain de mie or Pancarré	Sandwich bread that has been sweetened.
Pan dulce	A variety of pastries including bread
Pandesal	Bread roll made from what flour, eggs, salt and yeast.

Source

Pandoro	Originating from Italy Pandoro, is a sweet bread made from wheat flour eggs, butter and sugar. This bread is baked traditionally on special occasions such as Christmas
Pane carasau	Dry flat bread with a long shelf life, this is made from baking separated sheets from baked flat bread.
Pane di Altamura	Bread originating from Italy, made from a specific variety of wheat flour.
Pane ticinese	White soft bread originating from Switzerland
Panettone	Italian sweet bread prepared using flour, fruits and raisons

(Treuille and Ferrigno, 2008)

Source

Table 1d, Types of Bread

Papadum or papad	Crispy thin bread served as an appetizer or a side dish to main dishes.
Paratha	Originating from India, Paratha is a flat bread made from whole wheat flour.
Parotta or Barotta	Flat bread from southern India, made from whole wheat flour
Paximathia	Originating from Greece, Paxmathia is a hard bread made from whole wheat flour and barley
Pogača	Originating from Turkey is a type of bread that undergoes a twostep baking process and is usually made from whole wheat flour.
Potato bread	Bread made from a composite flour of potato and wheat flour. Other ingredients are added as per desired finished product.
Potbrood	Baked using a pot buried in the ground using wheat flour. Potbrood is common in South Africa
Rice bread	White soft bread made from rice flour
Roti	Main ingredient for Roti is whole grain wheat flour that has been ground a stone.
Rugbrød	Also known as dark-Rye bread. Rugbrød originates from Denmark. Made from rye flour
Rye bread	Made from rye flour, colour variations are observed in the finished bread as a result of the nature of the rye flour used.
Sangak	Wheat flour flat bread, main ingredients are wheat flour and sourdough. Sangak originates from Iran.
Sourdough bread	Sourdough has a sour taste due to the acid produced in the fermentation of the dough, giving sourdough bread a unique taste and appearance.
Spelt bread	Made from spelt with a nutty flavour and red in colour
Sprouted bread	A type of bread made from sprouted (germinated) whole grains
Tiger bread	Common in the United states, rice paste, and sesame oil are the main ingredients for Tiger bread, a pattern is formed on the surface of the bread after baking, hence its name tiger bread
Toasted bread	Browning of bread though exposure to heat.
Tortilla	Thin flat bread made from finely ground wheat flour. Originating from Mexico.
Zwieback	Made from baking a loaf and tasting the bread pieces till they are crispy brown slices

Source (Treuille and Ferrigno, 2008)

From Table1, about 80% of the different bread types globally are made using wheat flour. This trend is similar to the pattern to bread types in Ghana namely, butter bread, sugar bread, tea bread and brown bread. The reliance of the baking industry in Ghana on wheat flour makes the industry vulnerable to global pricing trends of wheat flour. Hence the development and use of local ingredients to reduce the cost of production and reliance on wheat flour has become very essential.

One such alternative being explored is the partial substitution of wheat flour with flour from tubers which is readily available and economically more competitive as compared to wheat flour. Studies have verified the use of yam flour, cassava flour (HQCF) and sweet potato flour as substitutes in bread making (Ciacco and D'Appolonia,2007).

2.2 High Quality Cassava Flour Production

The production of high quality cassava flour (HQCF)is a developing area in cassava value addition. Processing of harvested cassava into HQCF must be completed within 24 h of commencement. According to Dziezoave *et al*. (2006) high moisture varieties such as *agbelimaduade*, should be eschewed in HQCF production. Also, it is recommended that during production of HQCF strict adherence to good manufacturing practices is observed (Amegashie,2004).

HQCF is typically unfermented, white, smooth and odourless. It is used in the food industry mainly in bakeries and breweries. However, it can also be used as a raw material for the manufacture of gum, glues, plywood and pharmaceutical drugs.

HQCF differs from traditional cassava products such as *agbelima* and *gari* mainly due to the prevention of extensive fermentation during processing (Dziedzoave *et al.*, 2006).

The processing steps for HQCF production are shown in Figure1

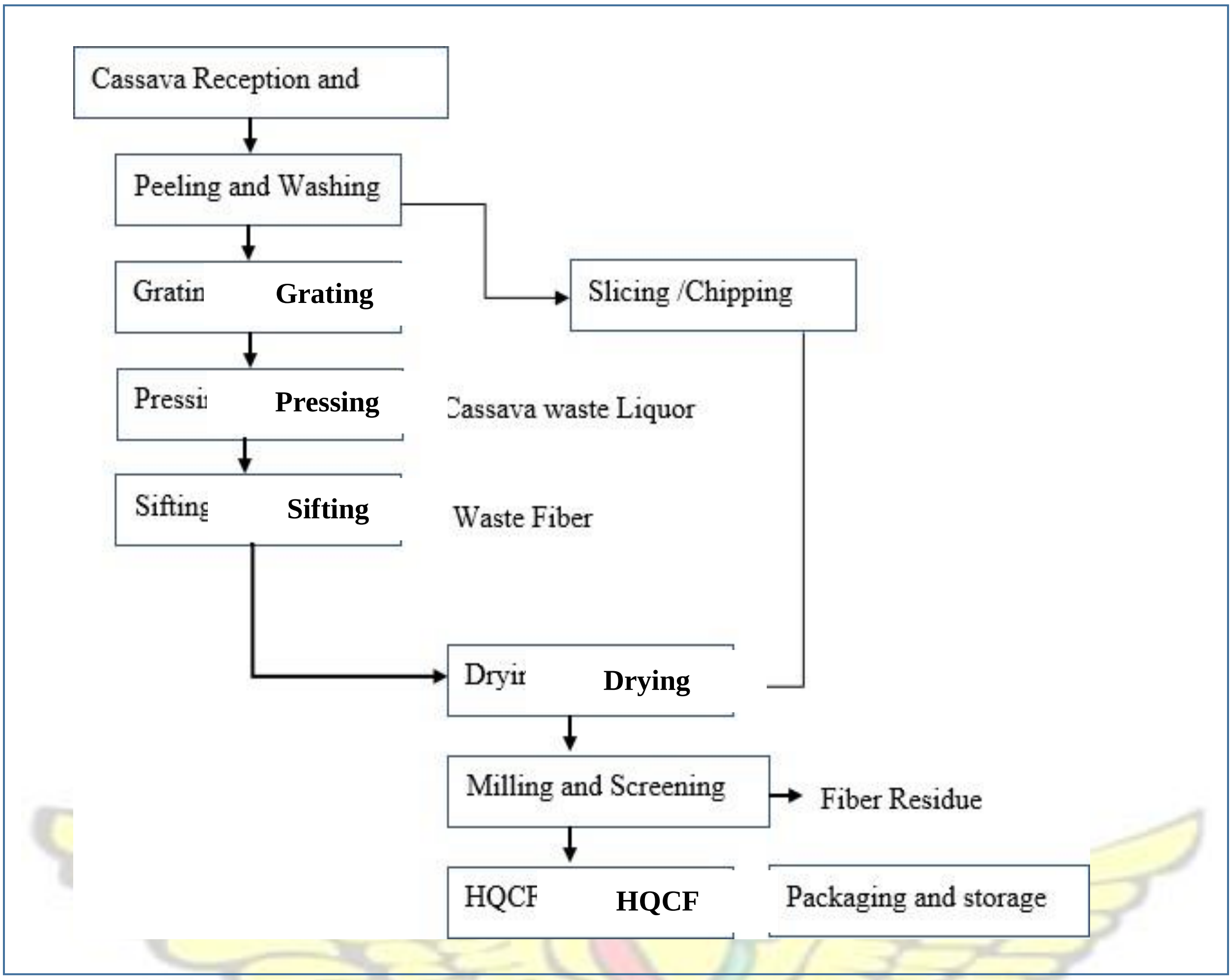

Figure 1: High quality Cassava Flour Production Process Flow (Amegashie, 2004)

2.2.1 High Quality Cassava Flour production process description

Press Method (Amegashie, 2004)

Raw material selection and storage: The recommended cassava to be used for processing is the well matured produce, preferable from low moisture varieties. This will assist in obtaining the desired quality of HQCF. Low moisture varieties of cassava will impact the drying step in HQCF production thus, the drying step will be shorter and more efficient.

Peeling: Peeling should be adequate to avoid peel fragments in flour. Peeling could be performed manually or through mechanical means.

Washing: Washing of the peeled cassava is performed using clean potable water, to remove sand particles and dirt.

Grating: Grating precedes disintegration of the cassava, facilitating efficient drying or moisture removal from the cassava.

Pressing: Pressing is done either using a manual screw press or a hydraulic press. The grated cassava may ferment if pressing is inefficient and unduly long. An efficient pressing step would significantly reduce drying time.

Drying: Drying is done at 60℃, either with a mechanical dryer or a solar dryer. Drying should not exceed 7 h and this is dependent on the load density and feed rate. For mechanical drying, a load density of 2.5 kg/m^2 is recommended whiles for solar drying 1.5 kg/m^2 (Dziedzoave et al, 2006). The target moisture content is between 8-10%. (Dziedzoave et al, 2006)

Milling and Packaging: After drying a hammer mill is used to mill the cassava grits. The resulting flour is screened using a screen of pore size 250µm. The screening reduces fibre and improves flour smoothness. Packaging of the final product should be in polyethylene lined polypropylene sacks, to avoid moisture uptake and pest ingress.

2.3 SWOT analysis for HQCF use

The potential of using HQCF as composite flour can be fully explored by analysing the strengths and weakness of its usage to maximize demand, focusing on an efficient supply chain.

Strengths

a) High consumption of bread amongst populace
b) Growing HQCF production sector Weakness
a) Response of some consumers to HQCF based products is unknown and undocumented
b) Low substitution rates of wheat flour with HQCF, currently only 10% - 30% substitution of wheat flour by HQCF has been validated.

Opportunities

a) HQCF is competitive when compared to wheat flour.
b) Changing climatic conditions impacting volumes of wheat production.

Threats

a) Cheaper wheat flour from Turkey
b) Low demand for High Quality Cassava Flour
c) Few high-quality cassava flour processing facilities.

Properties of HQCF is as follows:

Table 2 Quality Parameters of HQCF (*Dziedzoave et al*, 2006)

Characteristics	**Levels**
Moisture Content	8-10%
Starch Content	65-70%
pH	6-7

Total titratable acidity (as lactic)	<0.25%
Particle size	250-500µm
Colour	L*>99
	a*<8
	b*<(-4)
Total cyanogens	<10mg/kg HCNeq
Pasting temperature	<74℃
Cook Paste Viscosity	>750BU

2.3.1 Nutritive Value of High Quality Cassava Flour

Cassava has a low content of vitamins, proteins and amino acids, such as lysine **(**Balagopalan, 2002).

Table 3 Nutritional Composition of Cassava (Wenham, 1995)

Component	Percent (by weight)
water	62 – 65
Carbohydrate	32 -35
Protein	0.7 - 2.6
Fat	0.2 - 0.5
Fibre	0.8 - 1.3
Ash	0.3 - 1.3

Table 4 Nutritional composition of Cassava flour (Ogori, 2013)

Parameter	Value (%)
Ash	0.6

Moisture	10
Crude Fibre	2
Carbohydrate	67.5

2.3.2 Functional properties of High Quality Cassava Flour

The principal component of HQCF is starch. This starch is composed of two polysaccharides namely; Amylose and amylopectin. Amylose consists of α-D-glucopyranose units linearly connected by α (1-4) D-glucosidic linkages. Amylopectin however is structurally branched due to the presence of α (1-6) linkages (Eriksson, 2013). According to Olufunmilola et al. 2014, amylose fraction in the starch component of cassava flour is about 19.49% whiles that for wheat is 28.19%. Wheat dough with a high amylose fraction exhibit desirous bread property such as more volume, and more porous crumb structure (Lee and Lee, 2012). Starch from flour used in baking is a vital component of bread. It impacts the bread functionally and nutritionally (Lee and Lee, 2012).

The gelatinization and pasting of starch during baking is influenced by factors such as the baking temperature and water availability. Hence the variation of baking parameters such as temperature and baking time, is likely to have a considerable effect on the physical attribute of the finished products, invariably influencing consumer preference.

Retrogradation is a reaction which occurs when amylose and amylopectin chains in cooked gelatinized starch realign themselves as the cooked starch cools. Retrogradation expels water from the polymer network and this has a direct impact on consumer acceptability. In bread, retrogradation is termed as staling (Iten *et al*,2003). During staling, moisture is expelled with time from the centre of the bread (crumb) to the outer portion of the bread(crust). Hence the crumb becomes dry and brittle, whiles the crust becomes spongy and wet.

Chemically retrogradation in bread involves both amylose and amylopectin (Iten *et al*,2003) which are starch molecules in flour. Amylose is more readily retrograded as compared to amylopectin as structurally amylose is a smaller unbound molecule. Hence the higher the percentage amylose content the more readily the food item retrogrades (Iten *et al*,2003). Wheat flour has an amylose content of 26% whiles Cassava flour has an amylose content of 20.47% (Iten *et al*,2003). Thus, bread baked from 100% wheat flour has a higher tendency to become stale as compared to bread baked with substituted flour from tubers such as cassava mainly due to the higher percentage of amylose.

2.4 Bread making

In Ghana most bakeries produce bread employing the following key steps: selection and weighing of ingredients, mixing the ingredients, stretching of dough, portioning of dough, proofing, and baking. At the mixing, proofing and baking steps, dough is subjected to varying physical and chemical changes including shear and large extensional deformations.
These changes to the dough are impacted by temperature and water hydration (Rosell, 2011). The molecular structure of bread dough is mainly made up of proteins which are called Gluten (Rosell, 2011).

The different methods of bread making are shown in Fig 4.

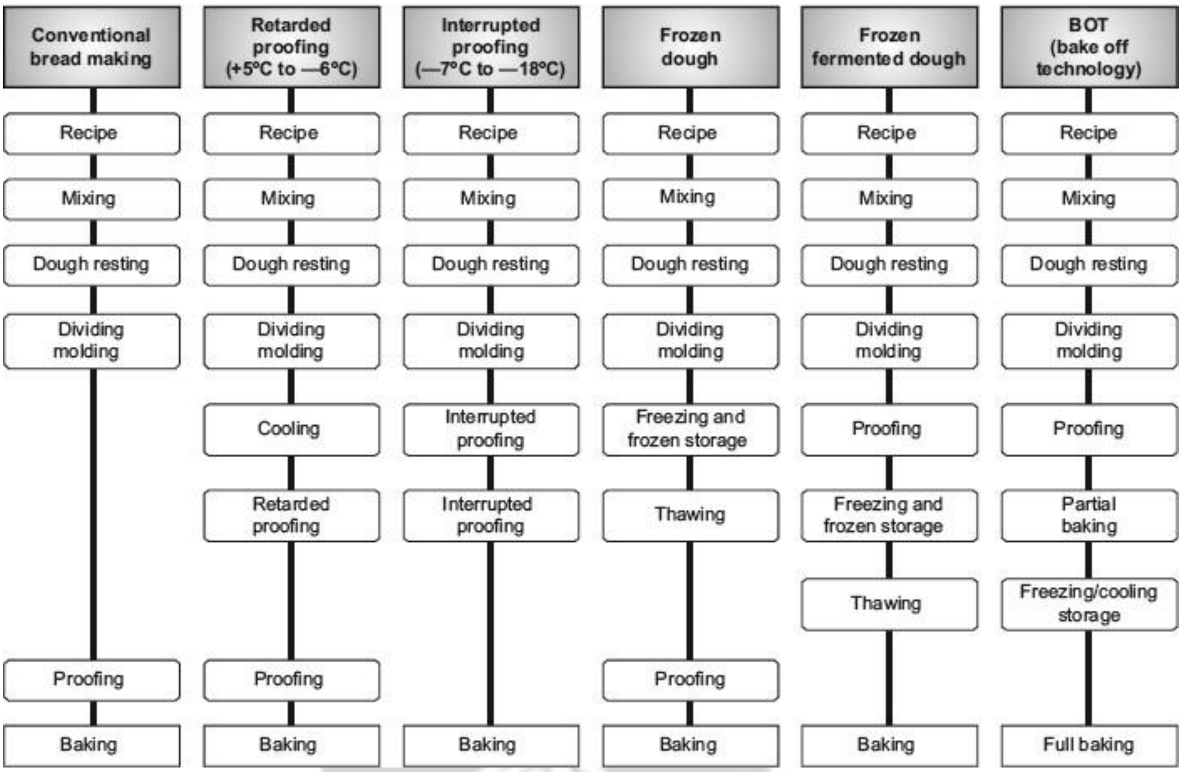

Figure 2 Different methods of bread making (Rosell, 2011)

During bead making several biochemical changes transpire that impacts the sensory attributes or the overall perceived quality of the finished product. At the proofing step during baking, yeast converts glucose from the flour into ethanol and carbon dioxide(Rosell,2011). The carbon dioxide produced is responsible for the rising of the dough, giving bread its desirable volume and spongy feel as the carbon dioxide is trapped by the dough structure.

$$\underset{\text{(Glucose from Flour)}}{C_6H_{12}O_6} \xrightarrow{\text{Yeast}} \underset{\text{(Ethanol)}}{2CH_3CH_2OH} + \underset{\text{(Carbon dioxide)}}{2CO_2}$$

During the baking step, sugars and amino acids present in the dough react in a non-enzymatic maillard reactions forming aroma compounds that are responsible for some of the characteristic olfactory sensory notes of freshly baked bread(Friedman,1996). Examples of such aroma compounds include maltol and isomaltol; produced from D-Fructose is responsible for crust flavour and aroma. Another aroma compound formed during baking as a result of maillard reactions is 2-acetyl-1-pyroline which is responsible for toast flavour(Friedman,1996). Thus, aroma compounds formed from the maillard reactions are responsible for the flavour and aroma of bread. Amino acids involved in the afore mentioned Maillard reactions include leucine, proline, isoleucine and serine.

The existence of multiple bread recipes is an indication that bread quality is dependent on the consumer perception which is a function of intrinsic factors such as age, sex, ethnicity and extrinsic factors such as environment (Rosell, 2011). Bread is said to be of good quality when the following parameters are acceptable to the consumer; i.e. appearance, taste, texture and aroma. The consumer attributes the quality of bread to perceived freshness of the bread.

2.5 Shelf Life

Quality parameters of foods such as taste, odour and appearance changes with time, this is mainly attributable to physical, chemical and microbial reactions (Smith et al, 2004). Most of the afore mentioned changes make food less acceptable. Food is at the end of its shelf life when desired quality parameters have been changed over time and the food is no longer acceptable (Elía, 2011). The defined parameters include aroma, appearance and texture or spoilage caused by microbial activity. The changes that occur in food that makes it less desired by consumers is generally termed as food spoilage (Elía, 2011).

Spoilage of bread is defined as the changes in the state of bread, making it unpalatable during consumption. This phenomenon can be generally classified into physical spoilage, chemical spoilage and microbial spoilage.

2.5.1 Physical Spoilage

The most common physical spoilage of bread is staling. Staling occurs during the post baking period, making bread less palatable when consumed. Stale bread is dry and leathery, with a hard texture.

During post baking the major changes that occur after baking includes moisture redistribution, starch retrogradation and loss of flavour (Elía, 2011).

Studies have suggested that migration of moisture from swollen starch to gluten causes staling (Elía, 2011). Hence bread having a high moisture content has the tendency to stale after baking. Further studies have validated that staling in bread is not only caused by moisture migration but also by the complex formation of starch components (non -linear amylopectin) lipids and flour protein.

There have been different methods developed to slow down the effects of staling in bread. Some of these methods include the use of chemical additives and the packing of baked bread with modified atmosphere such as Nitrogen and Carbon Dioxide (Lee and Lee, 2012).

2.5.2 Chemical Spoilage

Bread can undergo chemical spoilage or rancidity, resulting in off flavours and off odours decreasing shelf life. Rancidity occurring in bread can be categorized as hydrolytic or oxidative.

Oxidative rancidity is the process in which unsaturated fatty acids are broken down by free radical oxygen, resulting in the formation of aldehydes, ketones, and short chain fatty acids (Lee and Lee, 2012). When oxidative rancidity occurs to lipids in bread, the odour and taste of bread are changed, becoming less palatable. In Oxidative rancidity, fatty acid chains are oxidized due to the addition of oxygen on the C=C bond on the unsaturated fatty acid

(Robards *et al*,1988). Thus, the rate of oxidation is accelerated by the extent of unsaturation of the fatty acid and other external factors such as temperature, U.V light, and metal ion traces. Chemical reactions of oxidative rancidity can be summarized as follows:

- Initiation: The carbon - hydrogen bond of an unsaturated fatty acid is broken by light or sunlight in the presence of ions (Robards *et al*,1988).

$RH \rightarrow R^{\bullet} + H^{\bullet}$

- Propagation: Upon the formation of free radicals, they react with oxygen to form peroxide radicals:

$R^{\bullet} + O_2 \rightarrow ROO^{\bullet}$

The radicals then react with more molecules of the unsaturated fatty acid forming Hydroperoxides and free radicals (Robards et al. 1988)

$ROO^{\bullet} + RH \rightarrow R^{\bullet} + ROOH$

- Termination: The reaction is terminated when non-radical products form from free radicals (Robards *et al*, 1988). For example:

$R^{\bullet} + R^{\bullet} \rightarrow R\text{-}R$

$R^{\bullet} + ROO^{\bullet} \rightarrow ROOR$

$ROO^{\bullet} + ROO^{\bullet} \rightarrow ROOR + O_2$

Another cause of chemical food spoilage is hydrolytic rancidity which is due to release of fatty acids formed during hydrolysis of the fat by water. Hydrolytic rancidity is facilitated by moisture and endogenous enzymes resulting in the subsequent production of glycerol and malodorous fatty acids and a propane-1,2,3-triol (glycerol) in the reverse of the esterification reaction (Robards et al. 1988). The reaction for hydrolytic rancidity is as below:

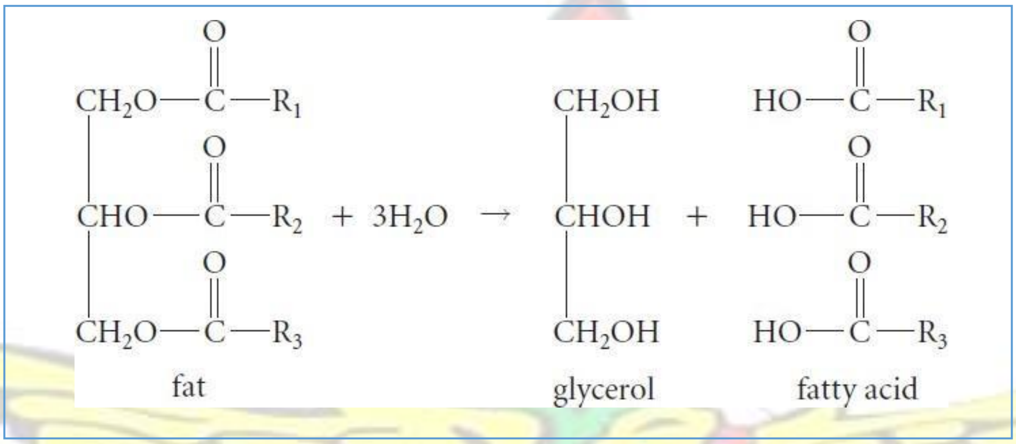

Figure 3: Hydrolytic Rancidity (Robards et al. 1988)

2.5.3 Microbial Spoilage

Microbiological spoilage of bread is the major cause of bread spoilage, thus limiting the shelf life of bread. This limited shelf life causes significant financial losses to the bakery industry, as finished baked products spoil in a brief time. The pivotal factor in microbial bread spoilage is unbound water (water activity ($a_{w)}$). For microbes to grow on bread (the leading to bread spoilage), the minimum water activity required is between 0.94–0.99 (Smith *et al*., 2010). The most occurring spoilage organisms in bread are mostly bacteria, yeasts and moulds.

The principal microbial spoilage of bread is caused by *Bacillus subtili* (Miñarro *et al*, 2010). This microbe is commonly found in raw ingredients used in baking. Spores from this microbe are resistant to high temperatures of the baking step, and grow during packing.

Moulds also cause bread spoilage; however baked bread is devoid of vegetative and spore moulds due to baking temperature. However freshly baked bread soon become contaminated because of contamination from post baking handling and bakery surfaces and equipment (Miñarro *et al*, 2010). Additionally, favourable conditions for mould growth are created when freshly baked bread does not cool sufficiently and is packed. This causes condensation on the inner surface of the packaging material, creating conducive condition for mould growth. *Neurosporacrassa spp* is an example of typical bread mould that produces spores that appears pink on the surfaces of contaminated bread (Smith et al, 2004). Another example of bread mould is *Penicillium spp*. The spores of penicillium appear as blue- green on the surfaces of contaminated bread (Smith *et al*., 2004).

Bread spoilage from yeast is the third type of microbial bread spoilage, which reduces the shelf life of bread. Some examples of yeasts commonly observed in bread spoilage are mainly *Pichia burtonii* (―chalk mould‖) and *Debaryomyces hansenii*. Contamination of bread by yeast is usually from unclean utensils and equipment. Hence clean surfaces and sanitized utensils are key to eschewing contamination of bread by yeast (Smith *et al*.,2004).

Generally, all the afore discussed forms of microbial spoilage, are influenced by the quality of bread which is also influenced by parameters such as water activity and quality of ingredients used. Hence to improve the quality of bread by fine tuning the baking process such as good manufacturing practices, baking temperatures and baking time could increase consumer acceptance of CCWF bread.

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2.6 Improvement in the baking of CCWF bread

2.6.1 Baking parameter variations

The effect of varying temperature–time combination during baking on the quality of CCWF bread (Shittu *et al*., 2007). The study highlighted significant changes in the quality of composite cassava-wheat bread produced with varying of baking temperature and baking time. Specific parameters that were impacted with the varying of baking temperature were bread loaf volume and crumb moisture, while baking time influenced the loaf weight, dried crumb hardness and density (Shittu *et al.*, 2007). However, the above study did not investigate the effect of variation of the baking temperature and baking time on the sensory attributes of CCWF bread. This study seeks to determine the effect of baking time on the sensory attributes and shelf life of CCWF bread, with the aim of improving the quality and overall consumer acceptability of CCWF bread.

Table 5 Properties used in the indication of the qualities of bread (Rosell, 2011)

Instrumental quality analysis	Sensory quality analysis
Specific volume Visual appearance	Specific volume Visual appearance
Crust colour Odour	Crust colour Odour
Crumb texture fresh Tactile and oral texture	Crumb texture fresh Tactile and oral texture
Hardness Taste	Hardness Taste
Springiness Overall acceptance	Springiness Overall acceptance
Cohesiveness Nutritional quality	Cohesiveness Nutritional quality
Chewiness Proximate composition	Chewiness Proximate composition
Resilience Carbohydrates	Resilience Carbohydrates
Crust indentation Proteins	Crust indentation Proteins
Hardness Fat	Hardness Fat
Area Dietary fibre	Area Dietary fibre
Crust thickness Glycemic index	Crust thickness Glycemic index
Water activity Load index	Water activity Load index

25

2.6.2 Available water

In bread, as in other food products, the presence of water can be classified into free, adsorbed and bound water. Water in food supports the growth of microorganisms, specifically free water /available water. Available water promotes the growth of microorganisms, enzyme and chemical reactions. Water activity is a ratio of the vapor pressure of free water in food divided by the vapor pressure of pure water at the same temperature (Mathlouthi, 2001). Water activity can also be measured as the water available for vaporization. Averagely, bread has a water activity of 0.95 (Smith *et al.*,2004). Water activity < 0.85 will not support the growth of microorganisms, however yeast can grow at a water activity as low as 0.70 (Smith *et al*, 2004). In relation to texture of bread, water activity plays an important role, in that the amount of water in bread determines the mobility of molecules of bread, thus impacting sensory attributes of the bread. Hence impacting consumer acceptability of bread (Smith *et al*, 2004).

2.6.3 Sensory parameters of CCWF bread

Sensory evaluation is a scientific tool which is used to measure and interpret those characteristics of food as perceived by the 5 human senses (sight, smell, touch, hear and taste).

One method employed in sensory evaluation is descriptive analysis, which provides descriptions of products using a sensory panel. Descriptive evaluation makes use of all sense i.e visual, auditory, olfactory, etc.–when the product is evaluated (Elía, 2011).

Descriptive analysis can be used to monitor competition (Elía, 2011). It is especially important to know in what ways competitive products differ; This data can be used to identify product improvement areas.

Descriptive testing can be used to evaluate product characteristics evolution as a result of product storage. Descriptive analysis is performed at the start of storage, provides a baseline upon which comparison can be made, especially when it is difficult to obtain a control, throughout the study as storage conditions such as freezing does not prevent product change and using fresh product introduces other sources of variability. Also, descriptive analysis can be employed in the identification of predefined product differences.

Descriptive sensory analysis can also be used in the study or analysis of bread, particularly the evolution of sensory characteristics of bread that impact consumer preference. The main sensory characteristics that impacts consumer preference for bread are: appearance (crust colour, and crumb colour,) aroma, taste (saltiness, bitterness, acidity), texture (crispiness, smoothness) and long-lasting taste (Vindras-Fouillet *et al*.,2014).

Taste attributes of bread such as bitterness or sourness impacts on the flavour of bread. The flavour property of bread depends on the type and quality of raw materials used to bake the bread. Flavour is also impacted by the baking process such as baking time and baking temperature. Other factors such as the presence of phenolic compounds, lipids and volatile compounds, free amino acids and peptides also impacts on the resulting flavour of baked bread (Vindras-Fouillet *et al*,2014) Sensory stimulation that is perceived nasally is referred to as aroma or odour. An example of off odour for bread is burnt aroma. Bread odour varies from the surface to the crust

The appearance of bread is perceived with the sense of sight and touch (Vindras-Fouillet et al,2014). The descriptive sensory attributes of bread can be categorized as follows; crumb, colour, crust colour or crumb structure (Vindras-Fouillet et al, 2014). During baking, components of the dough react producing the crust colour, this is mainly due to caramelization and Maillard reactions, between amino compounds and reducing sugars. During caramelisation reducing sugars present in the dough are oxidised at high baking temperatures to form brown pigments (hydroxy acetal furan and hydroxymethyl furan) and caramel flavours impacting on the taste and appearance of bread(Friedman,1996). Whiles during maillard reaction reducing sugars present in the dough, such as fructose , glucose and maltose reacts with the amino group of free amino acids such as leucine contributing to the characteristic golden brown colour of the bread crust and aroma compounds such as toast aroma(Friedman,1996).

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Materials

3.1.1 Sources of Materials

HQCF used in this study was sourced from CSIR –FRI in Accra, Ghana. The cassava used was *bankye hemaa* variety. Other ingredients used in this study were procured locally from Kaneshie market in Accra, Ghana these ingredients include wheat flour, sugar, margarine, salt, bicarbonate soda, yeast, nutmeg, non-dairy creamer and vegetable oil.

3.1.2 Sample preparation

Preparation of CCWF bread dough was done as outlined by Dziedzoave et al (2006), at the premises of flame bakery, Dome -Accra. The dough was prepared by substituting 12% by weight of wheat flour with HQCF and mixed thoroughly in a spiral dough mixer (VMI berto italia model 40 FA) with the other dry ingredients (sugar, salt, yeast, bicarbonate soda and baking soda). After homogenously mixing the dry ingredients for 16 min, water was added, and further mixing was done to obtain the CCWF dough.

As a control for the experiment, regular wheat flour dough was also prepared using wheat flour, sugar, salt, margarine, yeast, milk and water in a similar manner as was done for CCWF dough. Both the CCWF dough and wheat flour dough were then moulded by a mechanical bread moulder separately, portioned and placed in greased oven pans. The pans were then put into a bread proofing chamber for dough fermentation for 90 min at 30±2℃. After completion of proofing the fermented dough samples were put into the ovens for baking.

Baking of CCWF dough was done at 179℃ for 20 min, 25 min and 30 min. CCWF bread was removed from the oven at the afore mentioned baking times (treatments) and allowed to cool for 1 hr before carrying out assessments of the samples. The control 100% wheat flour bread

3.2 METHODS

3.2.1 Sensory Analysis

An acceptance test with a 9-point hedonic scale was used as the tool for sensory analysis. Twenty-five (25) panellists including 6 semi trained panellists were used in the experiment. The panellists were required to fill a 9-point hedonic scale for each sensory characteristics of samples analysed (Appendix A). Each panellist was presented with 2 slices of bread(18mm) per treatment (baking time) i.e. 4 different type of bread samples. The panellists were asked to taste from right to left, cleaning their pallets in-between samples by rinsing their mouth with water.

Panellists scored each sample using the 9-point hedonic scale (Appendix A), to access sensory parameters of the various treatments such as taste, texture, aroma and overall acceptability. The data obtained were statistically analysed using Microsoft Excel. The mean of the hedonic scores were used to determine significant differences between the different samples per sensory parameter and establish statistically if the treatments were significantly different from the control (100% wheat flour bread).

3.2.2 Microbial Analysis

Samples from the different treatments (baking time) were analysed after 48 hrs and 120 hrs, to determine the colony counts observed as the bread samples aged from day 2 to day 5. This was done to monitor microbial spoilage of the different treatments.

The Total Aerobic Count (TAC) was performed to establish the presence of aerobic microorganisms in the bread samples. The bread samples were analysed using the modified ISO 4833-1:2013 ISO/TC 147/SC 4/NP-3788:2002 methods. Serial dilutions to the sixth power were prepared using bacteriological peptone as diluent by weighing 10 g of bread into 90 ml of sterile diluent to obtain the stock from which subsequent dilutions were prepared.
An inoculum volume of 0.1 ml of the dilution was inoculated unto sterile plates of Plate Count Agar (OXOID CM0325) using the spread plate technique and incubated for 48 hrs at 37℃.The resulting colonies were recorded and the Colony Forming Units (cfu) calculated. The yeast and mould count were carried out using Potato Dextrose agar (PDA) as culture medium. The sample was prepared as discussed above and an inoculum volume of 1ml was spread on sterile agar plates containing PDA and incubated for 120 hrs at 25℃. The plates were observed for the presence of visible colonies of yeast and moulds. The observed colonies were enumerated and recorded.

3.2.3 Statistical Analysis

The mean scores obtained from the sensory acceptance test using the 9-point hedonic scale was analysed using the randomized design, using a one-way ANOVA employing Microsoft Excel and Minitab16 software. This was done to determine the significance difference between treatments (baking times). The data was said to be significantly different when the $P < 0.05$ at 95% confidence level. The afore mentioned statistical analysis was performed for each sensory characteristic i.e. Taste, texture, aroma and overall acceptance.
Microbial counts were recorded as base-10 logarithms of colony forming units of samples (log CFU g)

CHAPTER FOUR

RESULT AND DISCUSSION

4.1 Consumer Acceptance Test for Composite Cassava Wheat Flour and Wheat Bread

4.1.1 Taste

A consumer sensory test was conducted on the samples of bread produced using composite cassava and wheat flour (i.e 12% cassava flour) baked at the 3 different baking times i.e. 20 min, 25 min and 30 min. Regular sugar bread made from 100% wheat four was used as a control.

The panellist used was a blend of semi trained panellist (staff of flame bakery) and untrained panellist from various ethnic professions, gender, age and nationalities (Ghanaians, Ivorians and Angolans). To present a cross representation of modern mixed urban consumers that patronize sugar bread in Accra.

The parameters that were analysed by the panellists are; taste, texture, aroma and overall preference. To objectively assess panellist ratings of the afore mentioned parameters a 9point hedonic scale was employed, with 9 being dislike extremely and 1 being like extremely. The results of the sensory test for taste of the samples in indicated in figure 4

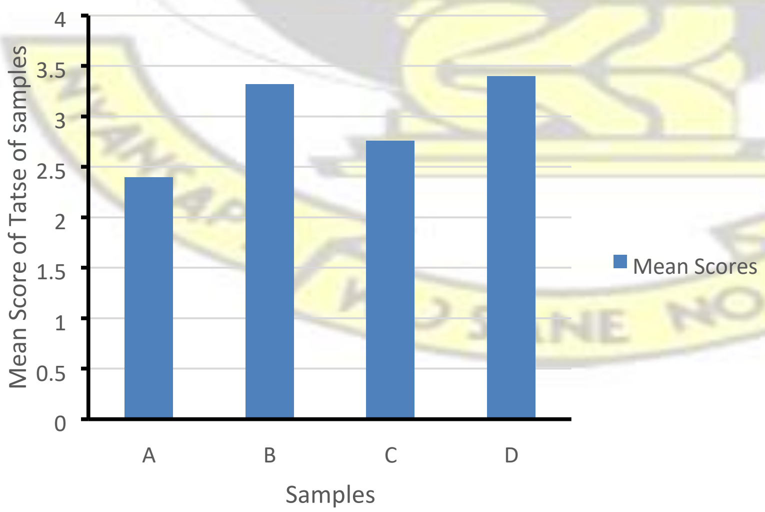

Figure 4 : Comparison of results of Taste: Sample A (100% wheat bread), Sample B (CCWF bread at 20 min baking time), Sample C (CCWF bread at 25 min baking time), Sample D (CCWF bread at 30 min baking time).

The ranking of the taste of bread made from CCWF flour baked at varying baking times was done against the control (100% Wheat flour bread). The mean from the 25-panellist used ranged from 2.4 –3.4, ranging between like very much and like moderately as per hedonic scale (Appendix A). None of the samples were ranked as dislike. The results indicated a high preference for the control (100% wheat bread) in terms of taste with the least mean score from the hedonic test of 2.4. This trend was also indicated by Eddy *et al* (2007), who reported that there was a higher liking of the taste of 100% wheat flour when compared with composite cassava wheat flour bread (Eddy et al,2007). Comparing the mean of the panellist scores for taste for the various samples against the Control (100% wheat flour bread), at a $p<0.05$ there was no significant difference between the control and composite cassava wheat flour bread baked for 20 mins. However, there was a significant difference in terms of taste between the control and composite cassava wheat flour bread baked for 25 mins ($p <0.05$). Taste is the perception through the mouth of the non-volatile components of bread; i.e. salty, bitter, sweet and acidic (Treuille and Ferrigno, 2008). Apart from ingredients and baking process such as fermentation, baking time and temperature traditions and cultures also influence the taste preference for bread. It comes to infer that all the panellist were more used to the taste of 100% wheat bread in terms of the combined effect of non-volatile compounds giving a unique blend of salty, bitter, sweet and acidic notes associated with what bread consumed daily (Treuille and Ferrigno, 2008); hence the preference for the taste of 100% wheat bread. However, the composite cassava wheat bread presented the panellist with different balance of the taste that consumers are not used to, hence the less preference for composite cassava wheat bread in terms of taste. The mean of results from Hedonic test of taste indicated that composite cassava wheat flour bread (12% Cassava flour) baked for 20 min is not significantly different from 100% Wheat flour bread.

4.1.2 Texture

The Texture of the bread samples was accessed by all 25 panellists, using the 9-point hedonic scale (Appendix A). The results of the assessment on Texture of the bread samples is summarized in figure 5 below:

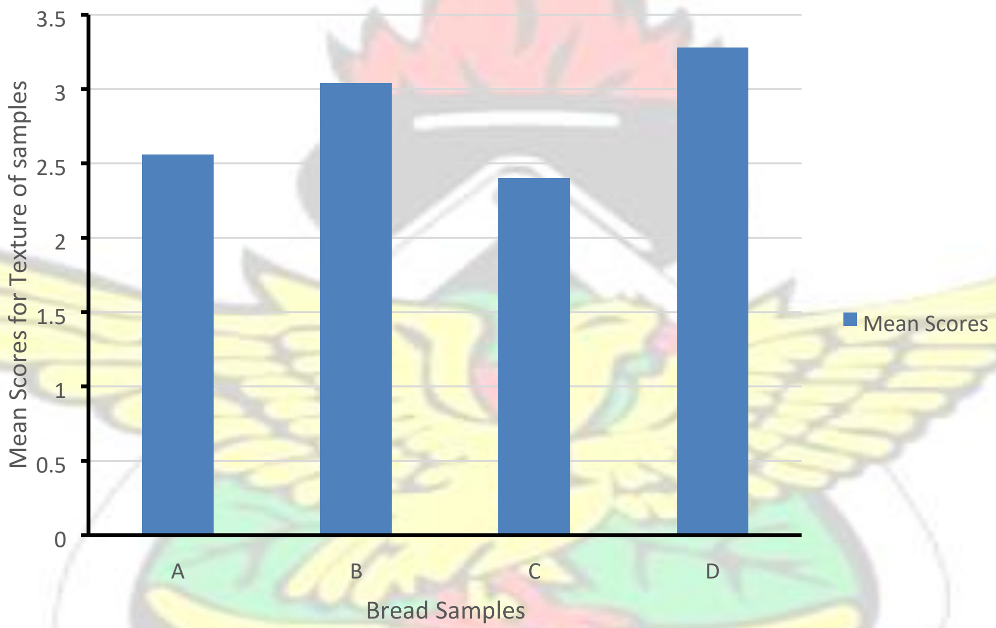

Figure 5: Comparison of results of Texture: Sample A (100% wheat bread), Sample B (CCWF bread at 20 min baking time), Sample C (CCWF bread at 25 min baking time), Sample D (CCWF bread at 30 min baking time).

The least mean value from figure 5 is sample C with a mean value of 2.4 followed by sample A with a mean value of 2.56. The highest mean value was sample D with a mean value of 3.28.

As per the hedonic scale used, this implies that majority of the panellist preferred the texture of CCWF bread baked for 25 min as compared to the texture of other samples, with the texture of sample D (CCWF bread baked for 30 min) being least liked by the panellist. Also comparing the mean of sample B, C, and D with sample A at $p<0.05$, there was significant difference between each of the samples and sample A. Thus, with regards to texture, none of the samples was similar to that of the control. This confirms the findings by Salehifar et al (2010) which established that wheat flour protein variations had an impact on the sensory attributes of bread.

4.1.3 Aroma

The Aroma of bread is said to be caused by volatile compounds released (into the retro-nasal passage) during bread consumption (Rosell, 2011). These compounds are generated in maillard reactions during baking between amino acids and sugars (Rosell, 2011).

Results from the sensory assessment from the 25-panellist used in the study is as follows:

4

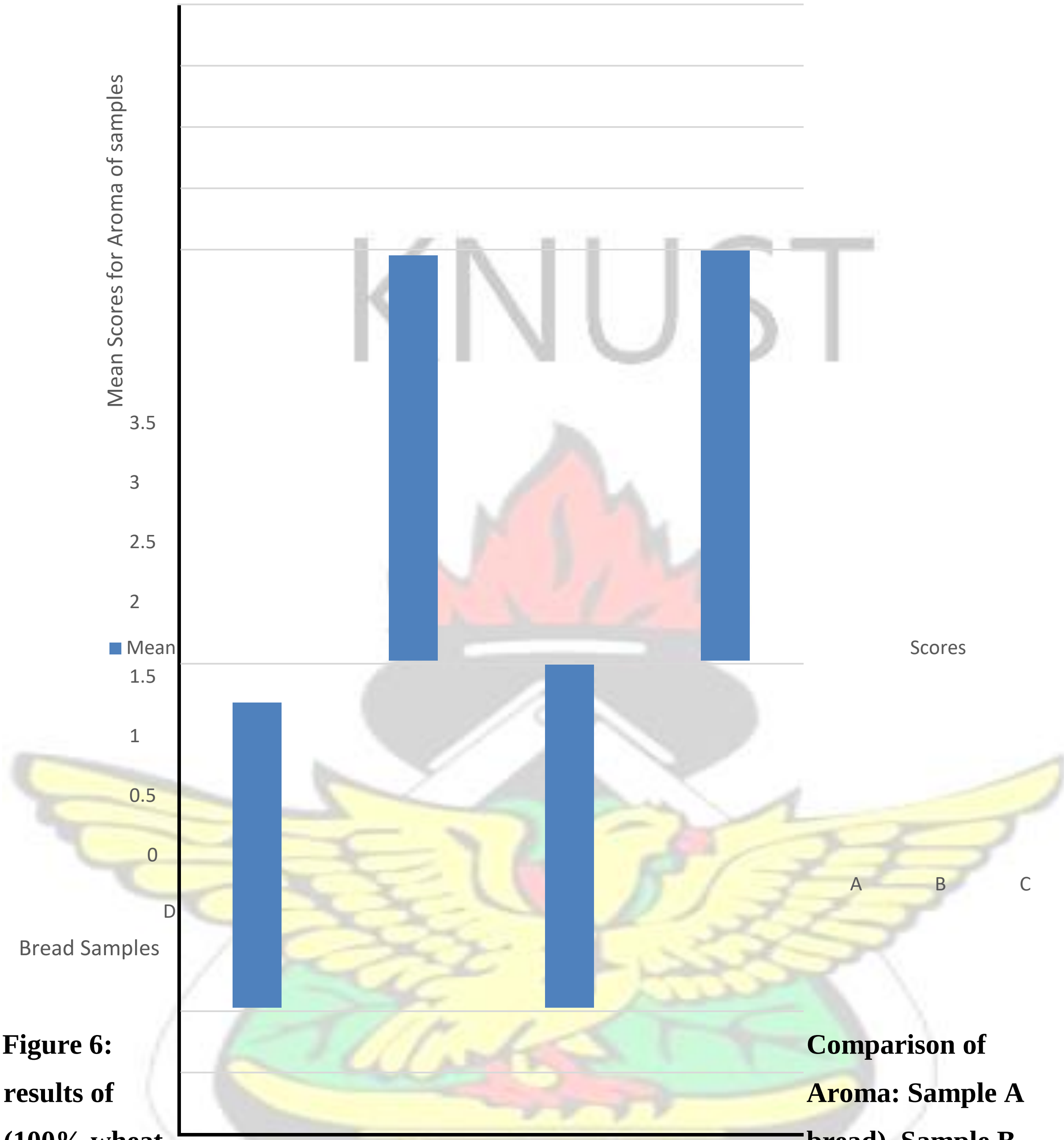

Figure 6: Comparison of results of Aroma: Sample A (100% wheat bread), Sample B (CCWF bread at 20 min baking time), Sample C (CCWF bread at 25 min baking time), Sample D (CCWF bread at 30 min baking time).

From Figure 6 above, sample A had the least mean with an average of 2.5, followed by sample C with a mean value of 2.88. Sample B and Sample D had an average value of 3.4. Interpreting the scores obtained for each sample as per the hedonic scale; indicates that sample A (100%

wheat bread)was the most preferred / liked by the panellist with regards to Aroma, whiles the least sample preferred is sample B (CCWF bread baked for 20 min) and

Sample C (CCWF bread baked for 30 min). When the means were subjected to a 1 factor ANOVA test at p<0.05; Samples B, C and D were found to be significantly different from sample A.

4.1.4 Overall Preference

Results from Panellist ranking of overall preference of the various samples are summarized in the table below:

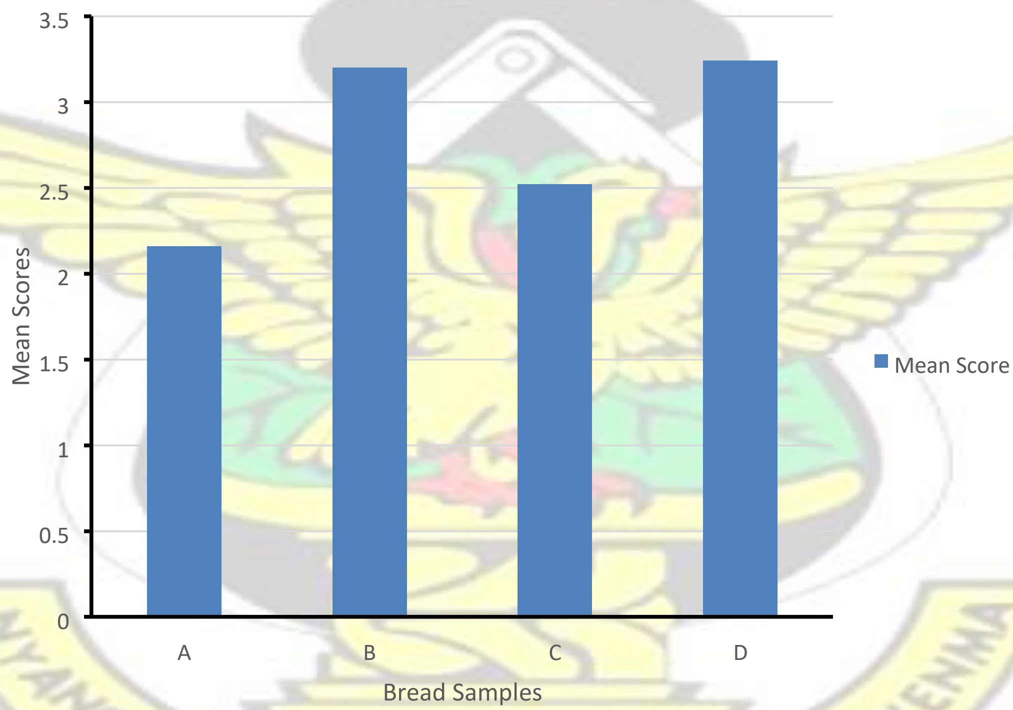

Figure 7: Comparison of results of Overall Preference: Sample A (100% wheat bread), Sample B (CCWF bread at 20 min baking time), Sample C (CCWF bread at 25 min baking time), Sample D (CCWF bread at 30 min baking time).

From the results in Figure 7 the most preferred bread was sample A, with a mean score of 2.16 followed closely by sample C (CCWF bread baked for 25 min), with sample B and Sample C being the least preferred by the panellist.

The, means for Sample A was compared with the mean for Sample B, C and D. Statistically the means of Sample B and Sample C were significantly different from the mean of Sample A, with P values 0.000431 and 0.002369 respectively.

4.1.5 Total Aerobic plate count

The total aerobic count appeared to be decreasing with increasing time of baking. Sample A (Reference: 100% wheat flour bread) recorded the highest count and the sample D (CCWF bread baked for 30 mins) recording the lowest counts.

The assay after 120 hrs of storage of samples at 40℃ showed an increase in the load of aerobic organisms A Bonferroni analysis comparing the individual treatments showed the sample A (Reference: 100% wheat flour bread) to have been the source of variation with the counts before storage varying significantly from the counts after storage at $P<0.05$. Other treatments showed no significant difference in microbial load upon storage at $P>0.05$. The summary of results is given in Table 12.

Table 12 Total aerobic count of bread samples after incubation in cfu/g

Sample	Before	After
Reference	$7.8\times10^{6}\pm6.08$	$3.7\times10^{7}\pm3.00$
20mins	$5.8\times10^{4}\pm5.03$	$8.6\times10^{4}\pm9.16$
25mins	$2.8\times10^{5}\pm9.16$	$9.7\times10^{4}\pm5.03$

30mins	7.5×10^{4}±10.26	3.8×10^{5}±5.13

4.1.6 Yeast and Moulds Counts

The fungi assay featured yeast and moulds counts.

Table 13 Statistical analysis of total aerobic count on bread

Test	Source of variation	P value	CI
One way ANOVA	Column factor	<0.0001	
Two way ANOVA	Block effect	0.0001	
	Treatment effect	<0.0001	95%
Bonferonni	Ref	<0.001	
	20mins	>0.05	
	25mins	>0.05	
	30mins	>0.05	

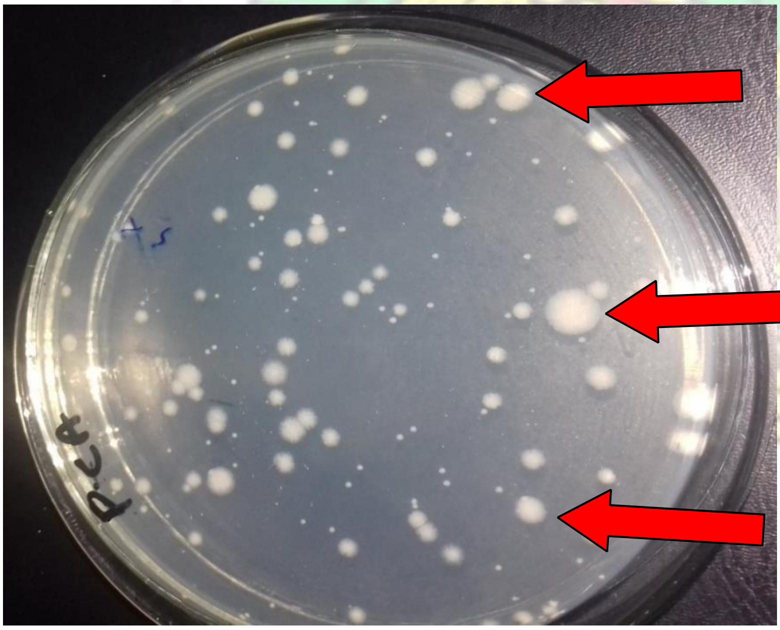

Figure 8: Aerobic microorganisms on Plate Count Agar after incubation at 37℃

The results of Yeast count after incubation at 37℃ indicated the absence of moulds after the period of incubation for the fresh sample but upon storage for 5 days moulds were observed. Yeast growth were observed after incubation in sample A (Reference: 100% Wheat flour bread) averagely $6.0\times10^{1\pm1.26}$ cfu/g with the other samples recording no yeast growth.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusions

Varying the baking time has been proven by the study to have an impact on the sensory attributes (Taste, texture, aroma and overall preference) of the CCWF bread with a fixed baking temperature of 179℃. During baking, caramelization and non-enzymatic maillard reactions produce aroma compounds and browning compounds responsible for the characteristic flavours and colours that impact on consumer preference on the taste, aroma and overall preference of baked bread. The aroma and browning compounds change with time during baking, thus impacting the resultant effect on the sensory characteristics of baked bread, impacting consumer preference.

CCWF bread baked for 25 mins was the most preferred when compared to the control (100% wheat bread). Indicating that when CCWF bread is baked for 25min at a temperature of 179℃ , there is the production of the appropriate balance of aroma, flavour and browning compounds that is most preferred by the consumer.

CCWF bread also demonstrated in the study to have a longer shelf life in terms of yeast growth than 100% wheat flour. This is influenced by the components of the dough as retrogradation occurred more readily in 100% wheat flour bread, thus the crust of the 100% wheat flour bread had more moisture available to support the growth of yeast. Although retrogradation occurred in the CCWF bread, it occurred at a slower rate, thus accounting for the observation of no yeast growth. The variation of baking time did not impact significantly on the shelf life of the bread.

The conclusions established by this study together with other publications or scientific studies conducted will be pivotal in promoting the use of high quality cassava flour in bread making. Using process control parameters to maximize competitive advantage. Additionally, the study has indicated that CCWF bread baked for 25 mins was most accepted by consumers hence less energy(fuel) can be used to baking as baking time is short (25mins).

5.2 Recommendations

1. Further studies need to be conducted on the highest percentage of HQCF that can be used in the production of CCWF bread that will help overcome some technical problems such as the soar taste and unpleasant aroma of baked bread when higher percentage of HQCF (<15%) is used to substitute wheat flour in bread making.

2. Further studies need to be conducted to establish the proximate properties of CCWF bread baked at different temperatures.

REFERENCES

Amegashie, S.G.Y 2004, *Analysis of value added cassava-based products and profitability of high quality cassava flour bakery products in Atebubu,* MPhil thesis, University of Ghana, viewed 14th May 2018, <http://ugspace.ug.edu.gh>

Antwi-Bediako, R 2008, *Community Based Natural Resource Management for Development: A Study of Selected Sites In The Nzema East District, Cape Coast*, MPhil thesis, University Of Cape Coast, viewed 14th May 2018, <http://uccspace.ucc.edu.gh>

Balagopalan, C 2002, Cassava utilization in food, feed and industry. In: J. T. a. A. B. R.J Hilocks, ed. *Cassava: Biology production and utilization.* Kerala: CAB International, pp. 301-318

Ciacco C.F, D'Appolonia B. L 2007, Baking studies with Cassava and Yam, Rheological and baking studies of tuber-wheat flour blends. *Cereal Chem 55(4)*, pp. 423-435.

Delwen, S 1997, Cereal Foods and Nutrition in Ancient Egypt, Nutrition 13(6), pp. 579-580

Dhingra, S, Sudesh, J 2004, Effect of Flour blending on functional, baking and organoleptic characteristics of bread. *International Journal of Food Science and Technology*, 39(1), pp.39, 213–222.

Dziedzoave, N.T, Graffham, A, Boateng, E. O 2006, *Training Manual for the Production of Cassava Based products.* 1 ed. Accra: National Board for small scale Industries.

Eddy, N. O, Udofia, P. G, Eyo, D 2007. Sensory evaluation of wheat/cassava composite bread Composite bread and effect of label information on acceptance and preference. *African Journal of Biotechnology*, 6(20), pp. 2415-2418.

Elía, M 2011, A procedure for sensory evaluation of Bread; protocol developed by a trained panel. *Journal of Sensory Studies*, 26(4), p. 269–277.

Eriksson, E 2013, *Flour from three local varieties of Cassava (Manihot Esculenta Crantz): Physico-chemical properties, bread making quality and sensory evaluation*, MSc thesis, Swedish university of agricultural sciences, viewed 14th May 2018, < http://stud.epsilon.slu.se>

Iten, S. H, Escher, F, Conde, B 2003, Staling of Bread: Role of Amylose and Amylopectin and Influence of Starch-Degrading Enzymes, Cereal Chem 80(6), pp.654–661

Lee, M.R, Lee, W. J 2012, Wheat Quality and Its Effect on Bread Staling, *Journal of Agriculture & Life Science*, 46(1), pp. 153-161.

Miñarro B, Capellas M, Normahomed I, Guamis M 2010, Influence of unicellular protein on gluten-free bread. *Eur Food Res Technol*, Volume 231, p. 171–179.

Mathlouthi, M. 2001, Water content, water activity, water structure and the stability of foodstuffs Food Control vol ,12(1), pp 409-417.

Friedman, M. 1996, Food Browning and Its Prevention: An Overview, Journal of agriculture and food quality, 44(3), pp 632-653

Nwanekezi, E. 2013, Composite Flours for Baked Products and Possible Challenges – A Review. *Nigerian Food Journal*, 31(2), pp. 18-17.

Ogori A.I. 2013, Physiochemical Properties of Dried Cassava Flour from Balls and Chunks. International Journal of Scientific & Technology Research, 2(10), pp. 63-70.

Olufunmilola O, Oladunmoye, O.C, Aworh, Bussie, M.D, Ochuko, L, Erukainure 2014, Chemical and functional properties of cassava starch,durum wheat semolina flour, and their blends. *Food Science & Nutrition*, 2(2), p. 132–138.

Robards, K, Kerr A.F, Patsalides, E 1988, Rancidity and its Measurement in Edible Oils and Snack Foods. *Analyst*, Volume 113, pp. 213-220.

Rosell, C. M 2011. The Science of Doughs and bread quality. In: *Flour and Breads and their Fortification in Health and Disease Prevention, UK*: Elsevier Inc, pp. pp.3-14.

Salehifar, M, Ardebili, M.S, Azizi M.H 2010, Effect of wheat flour protein variations on sensory. *Journal of food science and Technology*, 30(3), pp. 833-837.

Schroeder, E 2018, Wheat consumption in Ghana on small upswing, viewed 15th May 2018, <http://www.world grain.com/articles/news_home/World_Grain_News/2018/02/Wheat_consumption_in_Ghana_on.aspx?ID=%7BDF565ECB-1321-46EF-86E2-96F4228DA563%7D&cck=1>

Shittu T.A, Raji A.O, Sanni L.O 2007, Bread from composite cassava-wheat flour: I. Effect of baking time and temperature on some physical properties of bread loaf. *Food research International*, Volume 40, pp. 280-290.

Smith, J.P, Daifas D.P, El-Khoury W, Koukoutsis, J 2004, Shelf Life and Safety Concerns of Bakery Products—A Review. *Critical Reviews in Food Science and Nutrition*, 44(1), pp.19-55.

Treuille, E, Ferrigno, U 2008, Bread Revised,2nd edn, DK Publishing, London, UK.

USDA Foreign Agricultural Service 2014, *Ghana: grain and feed update*, viewed 15th January 2018,

<https://www.fas.usda.gov/data/ghana-grain-and-feed-update-0 >

Vindras-Fouillet, C, Ranke, O, Anglade, J. P, Taupier-Letage, B 2014, Sensory Analyses and Nutritional Qualities of Hand-Made Breads with Organic Grown Wheat Bread Populations. *Food and Nutrition Sciences*, Volume 5, pp. 1860-1874.

Wenham, J 1995, *Post-harvest deterioration of cassava - A biotechnology perspective*, Rome: Food and Agriculture Organization of the United Nations.

Appendix A - Sensory Evaluation Questionnaire

SENSORY ANALYSIS FORM

Name: ……………………………………. Occupation: …………………….

Sex: ……………………………………………. Date: …………..………….

Age: ……………………………………… Bread type: ………………………

Four (4) samples of bread has been provided labeled 389, 278, 262, and 109.

Please taste in given order and rinse your mouth with water after tasting each sample.

Indicate on the interval scale provided, your level of acceptance (1=Like extremely, 9= Dislike extremely) in the order; Taste, texture, aroma and overall preference.

Attribute: Taste

Sample	Like extremely	Like very much	Like moderately	Like slightly	Neither like/dislike	Dislike Slightly	Dislike moderately	Dislike very much	Dislike extremely

Attribute: Texture

Sample	Like extremely	Like very much	Like moderately	Like slightly	Neither like/dislike	Dislike Slightly	Dislike moderately	Dislike very much	Dislike extremely

Attribute: Aroma

Sample	Like e xtremely	Like very much	Like moderately	Like slightly	Neither like/dislike	Dislike Slightly	Dislike moderately	Dislike very much	Dislike extremely

Attribute: Overall Acceptance

Sample	Like extremely	Like very much	Like moderately	Like slightly	Neither like/dislike	Dislike Slightly	Dislike moderately	Dislike very much	Dislike extremely
					4				
		1	2	3		5	6	7	8

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Appendix B - Statistical output of Two-way ANOVA on bread samples

Parameter				
Table Analyzed	Data 2			
Two-way ANOVA				
Source of Variation	% of total variation	P value		
Interaction	27.55	< 0.0001		
Column Factor	10.08	0.0001		
Row Factor	60.74	< 0.0001		
Source of Variation	P value summary	Significant?		
Interaction	***	Yes		
Column Factor	***	Yes		
Row Factor	***	Yes		
Source of Variation	Df	Sum-of-squares	Mean square	F
Interaction	3	6.972e+014	2.324e+014	45.20
Column Factor	1	2.551e+014	2.551e+014	49.62
Row Factor	3	1.537e+015	5.124e+014	99.66
Residual	8	4.114e+013	5.142e+012	
Number of missing values	0			
Bonferroni posttests				
Before storage vs After storage				
Row Factor	Before storage	After storage	Difference	95% CI of diff.
Reference	7.650e+006	3.850e+007	3.085e+007	2.358e+007 to 3.812e+007
20mins	500000	870000	370000	-6.900e+006 to 7.640e+006
25mins	283000	980000	697000	-6.573e+006 to 7.967e+006
30mins	7000	35500	28500	-7.241e+006 to 7.298e+006
Row Factor	Difference	t	P value	Summary
Reference	3.085e+007	13.60	P<0.001	***
20mins	370000	0.1632	P > 0.05	Ns
25mins	697000	0.3074	P > 0.05	Ns
30mins	28500	0.01257	P > 0.05	Ns

Appendix C - Statistical output of One-way ANOVA analysis on bread samples.

Parameter			
Table Analyzed	Data 1		
One-way analysis of variance			
P value	< 0.0001		
P value summary	***		
Are means signif. different? (P < 0.05)	Yes		
Number of groups	4		
F	456.1		
R square	0.9942		
ANOVA Table	SS	df	MS
Treatment (between columns)	1.275e+014	3	4.249e+013
Residual (within columns)	7.452e+011	8	9.315e+010
Total	1.282e+014	11	

Appendix D – Raw data of Microbial count prior to cfu estimation

Table 10Microbial counts from Initial sample prior to storage

Sample		10_{-1}	10_{-2}	10_{-3}	10_{-4}	10_{-5}	10_{-6}
Reference	1	TNTC	TNTC	248	82	15	-
	2	TNTC	TNTC	257	71	10	2
	3	TNTC	TNTC	242	81	11	-
	Average	-	-	249	78	12	2
20 mins	1	TNTC	TNTC	57	5	0	0

	2	TNTC	TNTC	53	9	0	0
	3	TNTC	TNTC	63	4	0	0
	Average	-	-	58	6	0	0
25 mins	1	TNTC	277	31	0	0	0
	2	TNTC	289	22	2	0	0
	3	TNTC	271	29	0	0	0
	Average	-	279	27	0.7	0	0
30 mins	1	TNTC	67	4	-	-	0
	2	TNTC	87	6	-	-	0
	3	TNTC	73	7	3	1	0
	Average	-	76	6	3	1	0

*TNTC = Too numerous to Count

Table 11Total aerobic count from samples after storage for 120 hrs at refrigeration temperature (4℃)

Sample		10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}
Reference	1	TNTC	TNTC	TNTC	TNTC	34	0
	2	TNTC	TNTC	TNTC	TNTC	40	2
	3	TNTC	TNTC	TNTC	TNTC	37	0
	Average	-	-	-	-	37	0.7
20mins	1	TNTC	TNTC	78	15	0	0
	2	TNTC	TNTC	96	9	2	0
	3	TNTC	TNTC	84	14	0	0

	Average	-	-	86	13	1	0
25mins	1	TNTC	TNTC	93	21	0	0
	2	TNTC	TNTC	103	24	5	0
	3	TNTC	TNTC	97	16	4	0
	Average	-	-	98	20	3	0
30mins	1	TNTC	TNTC	32	7	0	0
	2	TNTC	TNTC	39	0	0	0
	3	TNTC	TNTC	42	3	1	0
	Average	-	-	38	3	0	0

*TNTC = Too numerous to Count

Table 12 Yeast count on from bread samples on PDA after incubation

Sample		10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}
Reference	1	6	0	0	0	0	0
	2	8	0	0	0	0	2
	3	5	0	0	0	0	0
	Average	6	0	0	0	0	1
20mins	1	0	0	0	0	0	0
	2	0	0	0	0	0	0
	3	0	0	0	0	0	0

	Average	0	0	0	0	0	0
25mins	1	0	0	0	0	0	0
	2	0	0	0	0	0	0
	3	0	0	0	0	0	0
	Average	0	0	0	0	0	0
30mins	1	0	0	0	0	0	0
	2	0	0	0	0	0	0
	3	0	0	0	0	0	0
	Average	0	0	0	0	0	0