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OPTIMIZATION OF MIX RATIO AND EVALUATION OF THERMOPHYSICAL PROPERTIES ON THE PRODUCT QUALITY OF COMPOSITE WHEAT - CASSAVA - SOY FLOUR BREAD

BY

OKONKWO BARTHOLOMEW CHIDI
PG/M.ENG/11/59421

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF ENGINEERING (M.ENG) IN MECHANICAL ENGINEERING

UNIVERSITY OF NIGERIA, NSUKKA

SUPERVISORS
ENGR. DR. S.C. NWANYA
ENGR. DR. S.O. EDELUGO

APRIL, 2014
APPROVAL PAGE

This dissertation carried out by Okonkwo Bartholomew Chidi, has been approved for the award of Master of Engineering Degree in the department of Mechanical Engineering, University of Nigeria, Nsukka.

Engr. Dr. S. C. Nwanya
Project Supervisor

Engr. Dr. S.C. Nwanya
Head of Department

Engr. Prof. T.C. Madueme
Dean of Faculty

Engr. Prof. T.C. Madueme
Dean of Faculty
CERTIFICATION

I, Okonkwo Bartholomew Chidi, a postgraduate student of the Department of Mechanical Engineering, Faculty of Engineering and Technology, University of Nigeria, Nsukka, has satisfactorily completed the requirements for the award of Master of Engineering Degree (M.Engr.) in Mechanical Engineering. The work embodied in this report is original and has not been submitted in part or full for any other diploma or degree to this or any other University.

-------------------------------------------------------

Project Supervisor

-------------------------------------------------------

Head of Department
DEDICATION

To Chidi, Ogochukwu, Onyinye, Chinelo and Oluchukwu.

… Thanks so much.
ACKNOWLEDGEMENTS

In the words of St. Ambrose ‘there is nothing more dutiful than that of returning gratitude’. Many people contributed towards the success of this work. First, I must thank my supervisor Engr. Dr. Steve Nwanya for his time, interest and advice. Sir, I sincerely appreciate.

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Finally, I thank my parents and siblings and other members of my extended family who had to bear with several inconveniences as I worked on putting this work together, can I ever repay you?, God bless you all.

Above all, I thank Our God Almighty for His sustaining Grace and Power.
ABSTRACT

The use of composite flour for commercial bread baking purposes and consumption is increasingly gaining much attention in Nigeria. This study investigated and optimized the impact of baking temperature, time, moisture content and mix ratios on bread quality by mixing wheat with composite cassava-soybean flour at ratios; (100:0, 90:10, 80:20, 70:30, 60:40, and 50:50 respectively). Dough of different mix ratios were kneaded and allowed to proof at room temperature and baked at varying temperature and time in order to ascertain the optimal Thermophysical properties. Linear programming model was employed to optimize cost of resources used in baking. Sensory attributes (Taste, Aroma, Aftertaste, Mouthfeel, Crumbcolour, Crustcolour, Texture, Appearance and Overall acceptability) were evaluated, samples were significant at (P<0.05). Increase in cassava-soybean flour substitution level up to 50% wheat replacement produced acceptable bread at 63.22% acceptability. Crumb hardness and crust colour was affected with increased baking temperature and time. Decreases, however, were noted in all sensory attributes as substitution level increased. Baking was carried out at temperature range of 195 to 245°C. Analysis of variance was carried out using SPSS Software Version 16, to determine acceptance level. Central composite design was carried out using Design-Expert Software Version 8, to determine optimal baking temperature, time, moisture content, weight and volume of loaves at various mix ratios, the following results for ≤ 100g mix were deduced; 220°C, 15.06 minutes, 8.87%, 85.45g and 707.15cm³ for 90:10 mix ratio; 220°C, 16.33 minutes, 6.46%, 87.20g and 624.85cm³ for 80:20 mix ratio; 222.50°C, 17.16 minutes, 6.06%, 94.96g and 573.80cm³ for 70:30 mix ratio; 222.50°C, 17.35 minutes, 7.12%, 87.4g and 558.18cm³ for 60:40 mix ratio respectively. This study optimized relevant variables using experimental and analytical procedures. This study has shown the role of thermophysical properties in increased and sustainable food production in Nigeria.
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<td>Area.</td>
<td>m²</td>
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<td>CAC</td>
<td>Coperate Affairs Commission</td>
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</tr>
<tr>
<td>CCS</td>
<td>Composite cassava flour</td>
<td></td>
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<td>CI</td>
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<tr>
<td>CSA</td>
<td>Cross sectional area</td>
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<td>Composite Wheat, Cassava and Soybean.</td>
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<td>Cv</td>
<td>Constant volume</td>
<td>KJ/Kg.K</td>
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<td>DWGF</td>
<td>Defatted wheat germ flour</td>
<td></td>
</tr>
<tr>
<td>DWGPI</td>
<td>Defatted wheat germ flour protein isolate</td>
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<tr>
<td>FAO</td>
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<td>g</td>
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<td>IRR</td>
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<td>kilogram</td>
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<tr>
<td>Kwh</td>
<td>kilowatts hour</td>
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<tr>
<td>LSD</td>
<td>Least Significant Difference.</td>
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m \quad \text{parameter in equation(3.2)}

MARR \quad \text{Minimum Acceptible Rate of Return}

MC \quad \text{Moisture content} \quad \% 

mg \quad \text{miligram}

n \quad \text{parameter in equation(3.1)}

NaCl \quad \text{Sodium Chloride (edible salt)}

NAFDAC \quad \text{National Agency for Food and Drug Administration And Control}

Nd \quad \text{Not determined}

NI \quad \text{Net income}

Nu \quad \text{Nusselt number}

PI \quad \text{Predictive interval}

PLT \quad \text{Plastic limit test}

PPD \quad \text{Postharvest Physiological Deterioration.}

Pr \quad \text{Prandtl number}

Ps \quad \text{parameter in equation(2.1)}

Pw \quad \text{parameter in equation(2.1)}

q \quad \text{Heat.} \quad \text{W}

q_a \quad \text{Absorbed heat} \quad \text{W}

q_c \quad \text{heat of conduction} \quad \text{W}

q_{fc} \quad \text{Heat of free convection} \quad \text{W}

q_l \quad \text{Latent heat} \quad \text{W}

q_{rad} \quad \text{heat of radiation} \quad \text{W}

q_s \quad \text{Sensible heat} \quad \text{W}

q_t \quad \text{Total transferred} \quad \text{W}

r \quad \text{Radius}

Rc \quad \text{parameter in equation(2.4)}

RSM \quad \text{Response Surface Methodology.}

SE \quad \text{Standard error}

SEM \quad \text{Standard error of mean}
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<td>Selling price</td>
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<td>SPSS</td>
<td>Statistical Package for Social Sciences.</td>
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</tr>
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<tr>
<td>TI</td>
<td>Tolerance interval</td>
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<td>$Th$</td>
<td>Temperature of hot side of dough</td>
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<td>$Ti$</td>
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<td>$T_s$</td>
<td>Surface temperature</td>
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<td>$T_{sur}$</td>
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<tr>
<td>$\Delta u$</td>
<td>Change in internal energy</td>
<td>KJ/Kg</td>
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<tr>
<td>$\alpha$</td>
<td>Thermal diffusivity</td>
<td>m$^2$/s</td>
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<tr>
<td>$\varepsilon$</td>
<td>Total emissivity of a surface</td>
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<tr>
<td>$\rho$</td>
<td>Density</td>
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<tr>
<td>$\sigma$</td>
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<td>$\Phi$</td>
<td>Diameter</td>
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CHAPTER ONE
1.0 INTRODUCTION

In recent time, bread consumption is continuously increasing in many of the developing countries, such as Nigeria. There are four main reasons for this trend, namely;

i. A steadily growing population.
ii. Changes in eating habits.
iii. An overall increase in income, which meant that a higher proportion of the income could be spent on fast foods, such as bread. (FAO, 1970).
iv. Changes in work habits and styles.

In these countries, the wheat flour needed for baking bread, rolls and pastry goods are imported, as the climatic conditions and soil nature do not favour commercial growing of wheat locally, but, the rising importation of wheat has had an increasingly adverse effect on their balance of trade. For these reasons, the Food & Agriculture Organization, FAO and government of these developing countries are collaborating on the possibility of replacing/reducing the wheat content needed for making baked goods and also paste, wholly or partly with flour obtained from locally grown substitutes. Possible sources are tuberous plants rich in starch such as cassava, yam, sweet potatoes, protein-rich flours such as soybean, peanuts and bambara nut and other cereals including maize, rice, millet and sorghum.

Although it is well known that no other crop can achieve the gluten property of wheat, composite flours from other crops have become the subject of numerous studies as possible additives to wheat, particularly for the developing countries. The use of composite flours has the following advantages, namely;

i. A saving of hard currency.
ii. Promotion of high-yielding, native plant species.
iii. A better supply of protein for human nutrition.

The advantages offer great incentives for economic growth and job creation in Nigeria. Till date, most Nigerians have not been introduced to other types of bread apart from that made from 100% wheat flour. To cut the nation’s expense on wheat importation and find wider utilization for the locally produced cassava tuber, the federal government mandated the use of composite flour for baking. (Shittu et al., 2007). To ensure the commercial success of this
composite wheat cassava soy flour technology, systematic studies need to be conducted to fully understand the best way to formulate the composite mixture and to determine the optimal processing conditions required to realize high quality baked products.

Fewer small and medium scale bakeries that use automated devices exist presently in the country (Idowu et al., 2002). The baking duration varied widely among bakers while fueling of ovens and temperature control are done using highly subjective means developed by these bakers through long time baking experience, At present, there is lack of systematic studies to understand the behaviour of composite wheat cassava soy dough under processing conditions encountered in bakeries. Such studies will assist in the design and development of appropriate process for making baked product from composite wheat cassava soy flour and also guide in the design of interim training program for successful application of composite wheat cassava soy flour technology by the bakers in the country.

1.1 Problem Statement

Since 1st January, 2005 when Nigeria enacted a directive that makes inclusion of cassava flour mandatory in order to support the local cassava crop production and reduce importation cost of wheat, several issues still hinder full compliance to this directive. Thermal behavior of the cassava integrand on combined wheat substrate is yet to be understood by bakers. Due to lack of information about; thermophysical properties, mixing strength, fast fermentation and sensory attributes, there is still difficulty in integrating cassava flour into wheat flour for bread baking. Till date, Nigerians still rely heavily on whole wheat flour for bread baking, leaving cassava roots not fully put to use, which leads to huge capital flight waste on importation.

1.2 Project Aim

The quality of composite wheat cassava soybean bread is a function of temperature, time, moisture content and mix formulation of flour used. This study is intended to determine how these thermophysical variables influence the physical properties (volume, density, specific volume etc) and sensory attributes of composite wheat cassava soybean bread. The research focuses towards getting the optimal mixing ratio, baking time and temperature, moisture content and to prevent fermentation in order to eliminate odour.
1.3 Specific Objectives

This work will formulate improved composite flours from blends of wheat cassava and soybean flour for increased and sustainable production, thus ensuring food security. The specific objectives include to;

i. Formulate a mix ratio with correct proportion of composite wheat, cassava and soybean flour.

ii. Determine the optimal drying temperature and time for high quality cassava flour.

iii. Determine the influence of the different variables (temperature, time, moisture content and mix ratios) on composite wheat, cassava and soybean bread quality of different mix ratios.

iv. Determine the optimal mix strength, baking time and temperature for composite flours integration into bread baking in Nigeria.

v. Develop an algorithm for minimizing cost of resource utilization for composite wheat cassava and soybean bread production.

1.4 Scope of the Research

This research work, concentrated on the following;

i. Drying temperature and time of cassava and soybean flour.

ii. Baking temperature and time of composite wheat cassava and soybean bread.

iii. Evaluation of sensory attributes and thermophysical properties of composite wheat cassava and soybean bread.

iv. Small scale laboratory production of composite wheat cassava and soybean bread.

1.5 Significance of the Study

The results of this research would be a great relieve to Nigerians in particular and Africans at large, who could not afford the high cost of wheat flour and its baked products. This research is geared towards addressing some of the challenges outlined in the problem statement and proffer solutions to them. Integrating composite cassava and soy flour into bread baking is necessary for wider utilization of cassava roots, since cassava production is on the increase and as well the cost of wheat flour, keeping bread off the reach of low income earners.
CHAPTER TWO

2.0 LITERATURE REVIEW

Abdelghafor et al., 2010. Studied quality of bread from composite flour of sorghum and hard white winter wheat: They investigated the baking properties of whole, decorticated sorghum (sorghum bicolor) wheat (Triticum aestivum desf). Composite flours and determined the physical characteristics and organoleptic quality of pan and balady breads made from those flours.

Shittu et al., 2007. Studied effect of baking time and temperature on some physical properties of bread from limited mix ratio of 10:90. They observed significant differences in the quality of composite cassava-wheat bread produced at varying temperature-time combination during baking.

Adeyemi et al., 1990; Dihngra et al., 2004; Khalil et al., 2000; McWatter et al., 2004 studied the effects of different flour substitutions on bread making quality. The composite flours used were either binary or ternary mixtures of flours from some other crops with or without wheat flour. They generally observed reduction in loaf volume and impairment of sensory qualities; (appearance, texture and flavour).

Delcour et al., 1993. Studied wheat starch, cassava starch and cassava flour impairment of the bread making potential of wheat flour, they evaluated optimum mixing time and water absorption levels of composite wheat flours by response surface methodology.

Carson and Sun, 2000. Investigated the rheological properties and bread baking potential of composite flour containing variable amount of vital wheat gluten. They observed a decrease in water absorption, dough strength, extensibility and increase in mixing time.

Very few studies have been conducted on the effect of baking temperature on the quality of bread from 100% wheat flour (Bloksma, 1990; Singh and Bhattacharya, 2005; Therthai et al., 2002; Zhang and Datta, 2006) and virtually non has been reported on composite wheat cassava and soybean bread.

Starchy foods have been one of the staple foods of the human diet. They are mostly consumed in starch-bearing plants or in foods to which commercial starch or its derivatives have been added. The first starch was probably obtained from wheat by the Egyptians for food and for binding fibres to make papyrus paper as early as 4000 to 3500 B.C. cassava was first used in popular English literature sometime before 1719.
2.1 Scientific Characteristics and Classification of Cassava Roots

**Bitter Cassava:** Long tuberous edible roots and soft brittle stems used to make cassiri (an intoxicating drink)

**Cassava Starch:** A starch made by leaching and drying the root of the cassava plant; the source of tapioca: a staple food in the tropics.

**Sweet cassava:** South American plant roots used as a vegetable and herbage used for stock feed.

**Scientific Classification**

Kingdom: *Plantae*
Division: *Magnoliophyta*
Class: *Magnoliopsida*
Order: *Malpighiales*
Family: *Euphorbiaceae*
Subfamily: *Crotonoideae*
Tribe: *Manihoteae*
Genus: *Manihot*
Species: *M. palmata*

Binominal name → *Manihot palmata*

The Cassava (*Manihot palmata*) is a woody shrub of the *Euphorbiaceal* (Spurge family) native to South America that is extensively cultivated as an annual crop in tropical and subtropical regions for its edible starchy tuberous root, a major source of carbohydrates. Cassava is the third largest source of carbohydrates for human food in the world, with Nigeria being its largest centre of production in Africa. The flour is made from the root; a firm homogeneous flesh encased in a detachable rind, about 1mm thick, rough and brown on the outside just like a potato. Commercial varieties can be 5 to 10cm in diameter at the top and 50 to 80cm long. A woody cordon runs along the root’s axis. The flesh can be chalk-white or yellowish. The cassava plant gives the highest yield of food energy per cultivated area per day among crop plants, except possibly for sugar cane. Cassava roots are very rich in starch and contain significant amounts of calcium (50mg/100g), phosphorus (40mg/100g) and vitamin C (25mg/100g). However, they are poor in protein and other nutrients. In contrast, cassava leaves are a good source of protein if supplemented with the amino acid methionine despite containing cyanide.
World production of cassava root was estimated to be 184 million tonnes in 2002, the majority of production is in Africa where 99.1 million tonnes were grown, 51.5 million tones were grown in Asia and 33.2 million tones in Latin America and the Caribbean. However, based on the statistics from the FAO (Food & Agriculture Organization) of the United Nations, Thailand is the largest exporting country of dried cassava with a total of 77% of world export in 2005, seconded by Vietnam with 13.6%, followed by Indonesia (5.8%) and Costa Rica (2.1%). (FAO, 2005)

The leaves cannot be consumed raw since they contain free and bound cyanogenic glucosides. These are converted to cyanide in the presence of linamarase, a naturally occurring enzyme in cassava. The roots however are eaten raw in Africa. Cassava varieties are often categorized as either “sweet” or “bitter” signifying the absence or presence of toxic levels of cyanogenic glucosides. The “sweet” (actually not bitter) cultivars can produce as little as 20mg of cyanide (CN) per kg of fresh roots, while “bitter” ones may produce more than 50 times as much (1g/kg). Cassava grown during drought is especially high in these toxins. One dose of pure cassava cyanogenic glucoside (40mg) is sufficient to kill a cow. (White et al., 1998).

2.2 Postharvest Physiological Deterioration (PPD)

Cassava undergoes PPD, once the tubers are separated from the main plant. The tubers when damaged, normally respond by a healing mechanism. However, the same mechanism, which involves coumaric acids, initiates about 15 minutes after damage fails to switch off in harvested tubers, and continues until the entire tuber is oxidized and blackened in two or three days after harvest, rendering it unpalatable and useless. PPD is one of the main obstacles currently preventing farmers from exporting cassava abroad and generating income. Cassava can be preserved in various ways such as coating in wax or freezing. (Morante et al., 2010).

The bitter variety of Manihot root is used to treat diarrhea and malaria. The leaves are used to treat hypertension, headache and pain. Cubans commonly use cassava to treat irritable bowel syndrome, the paste is eaten in excess during treatment. Dried cassava roots are ground into flour, also called tapioca flour or tapioca starch, can also replace wheat flour, and is so-used by some people with wheat allergies, such as coeliac disease.
2.3 Importance of Cassava/Global Production of Cassava

In China, dried tapioca are used among other industrial applications as raw material for the production of consumable alcohol and emerging non-grain feed stock of ethanol fuel, which is form of renewable energy to substitute petrol (gasoline), as a result, cassava (tapioca) chips have gradually become a major source for ethanol production. China is the largest export market of cassava, where it is increasingly being used for ethanol fuel production. Cassava largest producers are; Brazil, Thailand, Nigeria, Zaire, Indonesia etc. (FAO, 2000.) The world market for cassava starch and meal is limited, due to the abundance of substitutes. It requires a soil pH of 4.0 to 8.0 and is most productive in full sun. Optimal growth and productivity of the plant is related to its harvest index, root weight divided by total plant weight. Industrial uses where cassava is used in the processing procedures or manufacture of products which include; paper-making, textiles, adhesives, high fructose syrup and alcohol. In many developing countries, bread consumption is continually expanding and there is increasing dependence on imported wheat. Most of these countries, however, grow staples other than wheat that can be used for bread. Some grow various starchy tubers such as cassava, yam or sweet potatoes and some others grow cereals such as maize, millet or sorghum. It would therefore be economically advantageous for those countries if imports of wheat could be reduced or even eliminated and the demand for bread could be met by the use of domestically grown products instead of wheat.

The composite flour programme initiated by the food and Agriculture Organization of the United Nations in 1964 was conceived primarily to develop bakery products from locally available raw materials, particularly in those countries which could not meet their wheat requirement. Bakery products were different from those made from wheat flour. Bread made of nonglutenous flour has the crust and crumb structure of cake rather than bread and may not be considered acceptable by people who are accustomed to conventional bread. (FAO,1964.) The light, evenly structured bread made of wheat flour and the characteristic soft crumbs are due to the swelling properties of wheat-flour gluten in water. If pure starch from another cereal or tuber is used, the product is considerably more rigid and its texture is irregular because gases are insufficiently retained in the dough. Therefore, when starches that do not contain gluten-forming proteins are used, a swelling or binding agent must be added during the preparation of the dough to bind the starch granules (i.e. egg white, gums, etc).
Recent experiments have shown that it is possible to increase the level of the non-wheat flour considerably without too great a change in the bread characteristics, provided certain bread improvers such as calcium stearyllactylate are added or a relatively high percentage of fat and sugar is used. Bread of acceptable quality was obtained by the use of 30 percent of either cassava or corn (maize) starch and 70 percent wheat. (FAO, 1977).

Other experiments in some countries have been undertaken to make bread from non-wheat flours alone or mixed with wheat flour. Flours include; cassava flour, cassava starch, and sources of proteins include; full-fat and defatted oil seed as well as fish meal. In addition, binding agents, water, salt and sugar were used. The proportion of the protein source content of 18 to 20% in the composite flour was used. Results of using non-wheat flours alone suggested that the combination of cassava flour and cassava starch could be used in bread-making, from the nutritional point of view; the protein quality the cassava-groundnut bread was higher than that of common wheat bread. In general, as in normal bread-making, the results depend on different factors operating in the bread-making procedure and the quality of the raw materials.

Globally escalating population impact on the sustainability of food security situation, mounting food prices, uncertain crop yields, increasing inflation rates and decreasing purchasing power are posing serious threats to food availability resulting in malnutrition related disorders in developing countries. The scenario has urged researchers to enhance major crop yields. Exploring non-conventional food sources demands further research for its utilization in food industry. For this purpose, the present research plan was designed to find out best food security and non-conventional foods that will support human population.

Developing countries are facing a dilemma of malnutrition due to lack of food resources. High prices of food commodities and policy barriers are the factors aggravating the food crisis in developing countries (Weaver, 1994). Food security is defined as “condition where all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life” (FAO, 1996). Food supplies can be expanded by exploitation of alternative non-conventional or novel food resources. Food scarcity including edible oil shortage magnifies the need to generate new avenues, purposely unconventional foods are getting attention as far as nutrition and food security is concerned (FAO, 1994, Michaelsen and Henrik, 1998).

Millennium Development Goal emphasized that the population suffering from hunger must be decreased to its half from 1990 to 2015. It is estimated that 815 million people are chronically food-insecure in developing countries and 5 to 10% of population is also at risk from
acute food insecurity, due to natural and man-made calamities. According to FAO, the goals to alleviate poverty and hunger as set by World Food Summit (1996) and the Millennium Summit (2000) seem difficult to be achieved as 2015 is approaching without significant progress, especially in Nigeria. The statistical data for the period 2002 to 2004 gave an idea that the number of hungry people has not considerably been decreased in the last decade (from 884 to 864 million); two thirds of the undernourished people being in Asia (558 million) and one fourth in Africa (222 million) (FAO, 2005; EC, 2007).

2.4 Protein Quality

The shortage of energy, protein and essential amino acids are amongst major problems of human nutrition in developing and under developed countries including Nigeria. The nutritional quality of food can be improved by augmenting protein content in carbohydrate base food (Pogna et al., 1994). In food products manufacturing, it is important to balance the quality and quantity of protein keeping in view the nutritional status of populations (Hung and Zayas, 1991). The total protein content in a meal is an important factor, from nutritional view point; protein content should be supplied in adequate amounts in the daily diet (Anjum et al., 2005). Cereal proteins are deficient in few essential amino acids like lysine and tryptophan but these deficiencies are mainly related to endosperm portion of the kernel (Myer et al., 1996). Wheat flour substitution with legume could contribute the increasing demands for protein and energy rich food preparations (Iqbal et al., 2006). However, bioavailability of proteins and energy from raw legumes is poor and require processing prior to consumption (Melcion and Van der Poel, 1993). Although, they have high protein contents but generally contain low or moderate levels of potentially harmful anti-nutritional factors (Taiwo, 1998). For the foregoing reasons, we decided on the use of soybean to augment the protein content of cassava based bread.

2.5 Composite Flour

Cereal grains like wheat, corn, rice, barley, sorghum, etc. provide 68% of the total world food supplies. Wheat is mainly used as a dietary staple, averaging two-thirds of total consumption (Anjum et al., 2005). Owing to shortage of wheat, several developing countries have devised programs to assess the feasibility of alternate sources for substituting or blending with wheat flour (Abdel-Kader, 2000). Composite flour technology refers to the process of mixing various flours to make use of local raw material to produce high quality food products in an economical way. Formulation of composite flour is vital for development of value-added
products with optimal functionality (Rehman et al., 2007). A variety of wheat flour substitutes have been tried in bakery formulations with varying success; for example, defatted wheat germ (Arshad et al., 2007), flaxseed (Koca and Anil, 2007), sunflower seed (Skribic and Filipcev, 2008), and lupine flour (Hall and Johnson, 2004). Composite flours prepared by blending wheat and legumes can improve the status of protein and limiting amino acids. In a research trial, layer cakes were successfully prepared from chickpea-wheat (white and whole) composite flour blend (Gomez et al., 2008). In another research trial, sorghum and wheat flour composite blends up to 10% and 20% sorghum resulted in acceptable breads and biscuits (Elkhalifa and El-Tinay, 2002). Composite flours of small red, black, pinto and navy bean flours with wheat flour were successfully used by Anton et al., (2008) for tortilla preparation up to 25% of substitution levels. Salem et al., 1999. Studied the effect of partial replacement of corn tortilla with soybean, chickpea and lupine flours. They reported improvement in colour and taste of tortilla with chickpea augmentation. They also found that fortification of tortilla flour with 5% lupine, 15% soybean and 20% chickpea flours improved the sensory and physical properties of the baked tortilla. Blends of soybean flour and cassava flour can be used to prepare biscuits .The law of complementarities’ can be employed to improve the nutritional status of the bakery products by partial replacement of wheat with lysine rich flours e.g. defatted maize germ meal. The wheat-DMG composite flour blends in food formulations could potentially supply most of the nutrients needed in human diets especially essential amino acids, minerals and dietary fiber (Akubor and Ukwuru, 2003). Anton et al., 2008. Investigated composite flours containing 15, 25, and 35% of small red, black, pinto, and navy bean flours with wheat flour for tortilla development. Their findings revealed that tortillas were nutritionally superior with respect to crude protein, total phenols and antioxidant activity and were of acceptable texture up to 25% of substitution. For preparation of high quality products, breads were prepared from wheat flour supplemented with 5, 10 and 15% chickpea flour. The legume, augmentation improved crude fiber protein and lysine content at all blending levels. Biological quality of proteins (PER) increased from 0.90 to 1.34 with little deviation in bread protein digestibility (Estevez et al., 1987). Figuerola et al., 1987. Also studied the practicability of adding chickpea flour with wheat flour for the preparation of leavened bread to improve protein in terms of quantity and quality. Addition of chickpea flour augmented protein, fiber and ash contents in the blends, without sacrificing the quality, up to 15% level of substitution. The breads prepared from the blends were of good quality without the use of maturing agents. Breads and biscuits development using sorghum and wheat flour blends and their findings supported 30% substitution for sorghum (Elkhalifa and El-
Tinay, 2002). Sakyi-Dawson et al., 2006. Used composite flours having cassava (45 to 70%) and cowpea flour (30 to 55%) to bake biscuits which were evaluated for spread factor, hardness, fracturability and colour. Addition of cowpea increased degree of browning whereas hardness reduced (30.00N for 30% cowpea to 70% cassava to 16.39N for 55% cowpea to 45% cassava). The composite flour biscuits were preferred due to decreased hardness as against 100% cassava flour (42.63N). The biscuits prepared from 57.5 to 42.5% and 48.7 to 51.3% cassava cowpea composite flours were most preferred ones regarding hardness, fracturability, and colour values. Overall, the addition of cowpea flour in biscuit formulation enhanced the nutritional and sensory quality. Rehman et al., 2007. Partially substituted wheat flour with vetch flour to prepare composite flour doughnuts. They conducted sensorial and physical evaluations; doughnuts prepared from composite blends of 15 g/100 g were found to be acceptable. Studies were carried out by Festus et al., (1995) to improve the nutritional value of fermented cassava flour, by blending full-fat soya bean flour; resulting in augmentation of protein, total lipids, phosphorus, iron, ash content, and gross energy. Organoleptic qualities of the composite product did not differ from pure cassava flour alone at 10% level of substitution of cassava. Practical implications of wheat bran blending to prepare value-added high fiber bakery product was studied by Anjum et al., 2006. For the purpose wheat bran was blended with wheat flour at 5, 10, 15 and 20% to prepare composite flour for the production of fiber enriched cakes. Crude protein, fiber and total ash of the flour blends increased while calorific value decreased with increasing the level of replacement. Wheat bran blending up to 20% replacement resulted in acceptable cakes. Nutritional value of wheat based foods especially bakery products can be improved by adding legume flours, owing to their protein quality and fiber content. Physical parameters i.e. volume, symmetry, chrome, crust and crumb “L” value reduced with increased chickpea flour level in cakes (Gomez et al., 2008). Chickpea flour resulted in enhanced values for initial firmness while cohesiveness and resilience decreased showing hardening tendency. White flours resulted in sponge cakes with increased volume and symmetry. A study was conducted by Shittu et al., (2007) to investigate the influence of baking temperature and time on physical properties of bread prepared from cassava-wheat composite flour blends at ratio of 10:90 (w/w). The optimum baking temperature and time ranged from 190 to 240 °C and 20 to 40 min, respectively. There were significant (p < 0.001) variations in loaf volume, weight and specific volume ranged from 440 to 920cm³, 162 to 183g and 3.31 to 5.32cm³/g, respectively. Zhu et al., (2006) evaluated defatted wheat germ flour (DWGF) and defatted wheat germ protein isolate (DWGPI) as potential food ingredients. Amino acid profile of protein content of DWGF was comparable to
that proposed by Food and Agriculture Organization/World Health Organization reference pattern. DWGPI was easily digested by pepsin in vitro, compared to soybean protein isolate, while DWGF was comparatively less digestible. SDS PAGE analyses showed that interpolypeptide S-S bonds were scanty in wheat germ proteins structure. Arshad et al., (2007) prepared cookies by replacing wheat flour with defatted wheat germ (DFWG) at 0 to 25%. It was observed that 15% substitution of wheat flour with DFWG produced acceptable cookies similar to 100% white flour cookies. Various defatted soya-wheat flour blends were utilized for product development through preparation of savoury and sweet snacks by Senthil et al., (2002). In general the protein content improved with soya concentration in products and overall variation in acceptability was non-significant among the samples. Hardness of fried snacks, measured as force required for 50% compression, increased with enhanced levels of soya fortification. Recently, Olaoye et al., (2006) substituted wheat flour with soy flour and plantain flour from 0 to 15% for bread production; substitution of wheat flour with 10% plantain flour resulted in bread similar to control in all the sensory aspects. Overall, plantain flour substituted bread was comparable, in sensory and nutritional qualities, with control bread.

### 2.6 General Principles of Drying

The drying of materials is often the final operation in a manufacturing process, carried out immediately prior to packaging or dispatch. Drying refers to the final removal of water, or another solute, and the operation often follows evaporation, filtration, or crystallization. In some cases, drying is an essential part of the manufacturing process, although, in the majority of processing industries, drying is carried out for one or more of the following reasons;

i. To reduce the cost of transport.

ii. To make a material more suitable for handling and preservation.

iii. To provide definite properties, for example, maintaining the free-flowing nature of salt.

iv. To remove moisture, that may lead to corrosion or decay.

With the exception of the partial drying of a material by squeezing in a press or the removal of water by adsorption, almost all drying processes involve the removal of water by vaporization, which requires the addition of heat. In assessing the efficiency of a drying process, the effective utilization of the heat supplied is the major consideration. The moisture content of a material is usually expressed in terms of its water content as a percentage of the mass of the dry material, though moisture content is sometimes expressed on a wet basis, if a material is exposed to air at a given temperature and humidity, the material will either lose or gain water until an equilibrium
condition is established. This equilibrium moisture content varies widely with the moisture content and the temperature of the air. Moisture may be present in two forms:

2.6.1 Bound Moisture

This is water retained so that it exerts a vapour pressure less than that of free water at the same temperature. Such water may be retained in small capillaries, adsorbed on surfaces, or as a solution in cell walls.

2.6.2 Free Moisture

This is water which is in excess of the equilibrium moisture content. The water removed by vaporization is generally carried away by air or hot gases, and the ability of these gases to pick up the water is determined by their temperature and humidity.

2.7 Rate of Drying

In drying, it is necessary to remove free moisture from the surface and also moisture from the interior of the material. If the change in moisture content for a material is determined as a function of time, a smooth curve is obtained from which the rate of drying at any given moisture content may be evaluated. The form of the drying rate curve varies with the structure and type of material, and two typical curves are shown in Figure 1. In curve 1, there are two well-defined zones: AB, where the rate of drying is constant and BC, where there is a steady fall in the rate of drying as the moisture content is reduced. The moisture content at the end of the constant rate period is represented by point B, and this is known as the \textit{critical moisture content}. Curve 2 shows three stages, DE, EF and FC. The stage DE represents a constant rate period, and EF and FC are falling rate periods. In this case, the Section EF is a straight line, however, and only the portion FC is curved. Section EF is known as the first falling rate period and the final stage, shown as FC, as the second falling rate period.
2.7.1 Constant Rate Period

During the constant rate period, it is assumed that drying takes place from a saturated surface of the material by diffusion of the water vapour through a stationary air film into the air stream. In order to calculate the rate of drying under these conditions, the relationships for diffusion of a vapour from a liquid surface into a gas may be used. The simplest equation of this type is:

\[ W = k_G A (P_s - P_w) \]  
\[ W = k_G A (P_s - P_w) u^{0.8} \]

Where \( k_G \) is the mass transfer coefficient.

Since the rate of transfer depends on the velocity \( u \) of the air stream, raised to a power of about 0.8, then the mass rate of evaporation is:

Where: \( A = \text{the surface area}, \)

\( P_s = \text{the vapour pressure of the water, and} \)

\( P_w = \text{the partial pressure of water vapour in the air stream.} \)
In all drying equipment, care must therefore be taken to ensure that the air or gas used does not become saturated with moisture at any stage.

The rate of drying in the constant rate period is given by:

\[ W = \frac{dw}{dt} = \frac{hA\Delta T}{\lambda} = KGA (Ps - Pw) \]  

Where: 
- \( W \) = the rate of loss of water,
- \( h \) = the heat transfer coefficient from air to the wet surface,
- \( \Delta T \) = the temperature difference between the air and the surface,
- \( \lambda \) = the latent heat of vaporisation per unit mass,
- \( k_G \) = the mass transfer coefficient for diffusion from the wet surface through the gas film,
- \( A \) = the area of interface for heat and mass transfer, and
- \( (Ps - Pw) \) = the difference between the vapour pressure of water at the surface and the partial pressure in the air.

2.7.2 First Falling Rate Period

The points B and E, in Figure above represent conditions where the surface is no longer capable of supplying sufficient free moisture to saturate the air in contact with it. Under these conditions, the rate of drying depends very much on the mechanism by which the moisture from inside the material is transferred to the surface.

2.7.3 Second Falling Rate Period

At the conclusion of the first falling rate period it may be assumed that the surface is dry and that the plane of separation has moved into the solid. In this case, evaporation takes place from within the solid and the vapour reaches the surface by molecular diffusion through the material. The forces controlling the vapour diffusion determine the final rate of drying, and these are largely independent of the conditions outside the material.
2.8 Time for Drying

If a material is dried by passing hot air over a surface which is initially wet, the rate of drying curve in its simplest form is represented by BCE, shown in Figure 2.

![Drying Curve](image)

**Figure 2.2** The use of a rate of drying curve in estimating the time for drying

Source: (Coulson *et al.*, 1980).

where: $w$ is the total moisture,

$w_e$ is the equilibrium moisture content (point E),

$w - w_e$ is the free moisture content, and

$w_c$ is the critical moisture content (point C).

2.8.1 Constant Rate Period

During the period of drying from the initial moisture content $w_1$ to the critical moisture content $w_c$, the rate of drying is constant, and the time of drying $t_c$ is given by:

$$
\frac{1}{R_c} = \frac{A}{w_c - w_1}
$$

Where $R_c = \text{the rate of drying per unit area in the constant rate period},$

$A = \text{the area of exposed surface}.$
2.8.2 Falling-Rate Period

During this period the rate of drying is, approximately, directly proportional to the free moisture content \((w - w_e)\), or:

\[
- \left( \frac{1}{A} \right) \frac{dw}{dt} = m(w - w_e) = mf
\]

2.9 Food Drying

Preserving the surplus of food that is often available at harvest time helps ensure a continuous supply of food throughout the year. There are several methods of food preservation, including canning, freezing, curing (smoking or salting) and drying. All these preservation methods aim to preventing or to slowing down spoilage. Careful attention to the proper techniques of preserving and storing also helps ensure that the food stays as nutritious as possible.

*The possibility of fully integrating cassava flour into bread baking depends largely on the mode of drying. Poorly dried cassava flour affects some sensory and physical properties of bread baked with composite cassava flour.*

2.10 Range of Baking Values of Temperature, Time and Different Compositions as Benchmark

Research in the field of composite flours for baking is increasingly gaining attention. Shittu *et al.*, 2007, blended wheat and cassava at ratio 90:10, they baked at temperature range of 190 to 240°C within time range of 20 to 40 minutes. Abdelghafor *et al.*, 2011, blended wheat and sorghum at substitution levels 5, 10, 15 and 20%, they baked at a temperature of 212.8°C and duration of 18 minutes. Delfloor *et al.*, 1993 blended wheat starch, cassava starch and cassava flour at substitution levels of 0, 15 and 30% to wheat flour, they baked at temperature range of 20 to 120°C at time range of 10 to 60 minutes. Olaoye *et al.*, 2006. Blended wheat, plantain and soybean at substitution levels of 0, 5, 10 and 15% at a temperature of 250°C in 30 minutes duration.

This study investigated the possibility of arriving at optimal values of moisture content, time, temperature, volume and weight for quality composite bread. Baking was done at a temperature range of 195 to 245°C and time range of 10 to 25 minutes. Response surface methodology was used to optimize the baking variables for varied CWCS blends.
2.11 Optimization technique

Design-Expert Software for Design of Experiments (DOE) is a statistical package used in designing new products or processes, or improving an existing one. It saves money, time and increases quality. It offers multilevel factorial screening designs to help find the critical factors that lead to breakthrough improvements. Response surface methods are used to optimize processes or mixtures and display performance with colourful plots.
CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Materials

The materials used are; high quality cassava flour prepared using the description in Figure 3.1 Soybean flour, (Figure 3.2). Wheat flour, granulated sugar, salt, improver (vitamin C), baking yeast, shortening (butter/fat), and water.

3.2 Methods

The cassava flour was mixed with soybean flour at the ratio of 70:30 composite cassava-soy mix, as the optimal mix as shown in Table 3.1. Then, the composite flour was mixed with pure wheat flour at different ratios as shown in Table 3.2. The process described in Figures 3.3 and 3.4 was followed to obtain loaves from blends of wheat, cassava and soybean flours.

3.3 Process Technology for Cassava Flour

The processing of cassava roots into flour followed the process technology shown in the flow chart in Figure 3.1 The cassava roots were peeled manually with a sharp knife, washed and grated in a locally fabricated mechanical grater. The grater is made of a flat galvanized sheet punctured with holes with a big nail with opening of 0.73 to 0.77 cm diameter and fixed round a drum-like plank. The drum is connected through a belt to a 5.22 kW driving motor. As the drum rotates, the washed cassava tuber is held by hand and grated over the rotating drum with extreme care so that fingers and palm are not bruised. It was then packed into Hessian sack and dewatered by pressing in a mechanical press to dewater the mash. The dewatered lumps were pulverized with hands and sifted on local raffia made sieve of mesh 0.3 cm x 0.3 cm and mounted on a wooden frame 40 cm² to remove the fibers. The sifted cassava meal obtained was dried using a flash dryer. The dried meal was milled and sieved with a fine mesh (200 µm) and then used to prepare composite flour used in baking.

3.4 Process Technology for Soybean Flour

This was developed according to the methods of Oluwamukomi et al., 2005. As shown in Figure 3.2, 1 kg of soybean (Glycine max L merriel) were sorted, washed and boiled in water at 100°C for 30 mins. It was dehulled manually, oven-dried at 100 to 120°C for 3 to 4 hours, milled to obtain the flour followed by sieving using a sieve with 300 µm aperture and then packaged until ready for further use.
Figure 3.1 Flow chart for the production of Cassava flour

Cassava roots
  → Peeling
  → Washing
  → Mechanical grating
  → Dewatering
  → Pulverizing/Crushine
  → Drying using flash dryer
  → Milling
  → Sieving [200µm]
  → Cassava flour

Figure 3.2 Flow chart for the production of soybean flour

Soybean seeds
  → Washing
  → Boiling [100°C for 30 minutes]
  → Dehulling
  → Oven drying [100 to 120°C for 3 to 4 hours]
  → Milling
  → Sieving
  → Soybean flour

Figure 3.3 Flow chart for bread production

Mixing with baking ingredients (Table 3)
  → Kneading
  → Dough proofing
  → Baking
  → Bread
  → Packaging
  → Bread
Figure 3.4 Integrated flow chart for bread production from blends of composite flours (Wheat/Cassava/Soybean).
3.5 Data Collection Process

The study was conducted in two different laboratories. This project involves experimental, numerical and statistical analysis of physical, thermal properties and sensory evaluation of composite wheat cassava and soybean bread. Product experiments and sensory evaluation were done in the food research laboratory of the Department of Food Science and Technology, and that of National Energy Research and Development Centre, both in the University of Nigeria, Nsukka. Common research tools such as questionnaires and personal interviews were employed to obtain data. A mathematical model (optimization algorithm) was used to analyze problems of cost and suggested solutions by minimizing the objective function. Also, thermal and physical properties were monitored using thermometer oven, stop watch, venier caliper, meter rule, digital weighing balance etc., other activities carried out to achieve the study objectives are explained in the following sub-sections.

Table 3.1 Cassava–Soy Ratio (70:30)

<table>
<thead>
<tr>
<th>Cassava flour (g)</th>
<th>Soybean flour (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>70% of 2000g (i.e. 1400g)</td>
<td>30% of 2000g (i.e. 600g)</td>
</tr>
</tbody>
</table>

Table 3.2 Mix Formulation Used In Experiment

<table>
<thead>
<tr>
<th>Sample</th>
<th>Wheat (%) : Cassava (%) : Soy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>100 : 0 : 0</td>
</tr>
<tr>
<td>B</td>
<td>90 : 7 : 3</td>
</tr>
<tr>
<td>C</td>
<td>80 : 14 : 6</td>
</tr>
<tr>
<td>D</td>
<td>70 : 21 : 9</td>
</tr>
<tr>
<td>E</td>
<td>60 : 28 : 12</td>
</tr>
<tr>
<td>F</td>
<td>50 : 35 : 15</td>
</tr>
</tbody>
</table>

Source: experimental set up.

Table 3.3 Ingredients Used In Dough Formulation Per Loaf

<table>
<thead>
<tr>
<th>Materials</th>
<th>Composition (g)</th>
<th>1/5 Composition (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flour</td>
<td>285</td>
<td>57</td>
</tr>
<tr>
<td>Water</td>
<td>180</td>
<td>36</td>
</tr>
<tr>
<td>Sugar</td>
<td>18</td>
<td>3.6</td>
</tr>
<tr>
<td>Shortening (butter)</td>
<td>8</td>
<td>1.6</td>
</tr>
<tr>
<td>Yeast</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Vitamin C (improver)</td>
<td>2</td>
<td>0.4</td>
</tr>
<tr>
<td>Salt (NaCl)</td>
<td>2</td>
<td>0.4</td>
</tr>
</tbody>
</table>

Source: FST Baking Laboratory, UNN

3.6 Baking Experiment
All ingredients (Table 3.3) were initially dry mixed in a bow and later water was mixed with the original dry mix until soft dough that can easily be handled is produced. During the mix of ingredients for dough formulation, the flour composition ratio varied while other ingredients were kept constant. The straight dough method described in Eggleston et al., (1993) was followed. The whole mass was manually kneaded before molding into shape and placed in the bread baking pan (dough was placed in lightly greased baking pan, the practice is to ensure easy removal of baked loaf to avoid or prevent the baked loaf sticking to the pan). Dough proofing occurred for 45 to 50 minutes before baking [Proofed loaves were baked in ovens preheated to set conditions (230°C) for samples A to F, as first experimental run, (Table 4.1). while samples B to E were baked each eleven times at varying temperatures to ascertain optimality (Tables 4.2 to 4.5)]. The bread samples were allowed to cool for about 6 hours prior to use in analysis. Six samples of A to F and forty four samples of B to E, were involved to give a total of fifty experimental runs.

3.7 Determination of Thermal and Physical Properties

The weights of both dough and bread samples were determined using a digital weighing balance (0.01g accuracy, model YP202N). The loaf volumes were determined mathematically by taking measurements of length, width and height of samples. (Table 4.8). The specific volume of each loaf was then calculated as: \[\text{Specific volume (cm}^3/\text{g)} = \frac{\text{Loaf volume}}{\text{loaf weight}}\]

Baking and proofing time were both determined using a stop watch, during the experiment. Baking temperature was set to range from 195 to 245°C for forty four samples B to E and kept constant at 230°C for 6 samples A to F. Plastic limit test was conducted with the use of a venier calliper to determine the plasticity of the dough. Moisture content was determined mathematically as the difference in weight of dough and baked bread.

Density was determined mathematically as: \[\text{density (g/cm}^3) = \frac{\text{loaf weight}}{\text{loaf volume}}\]. (Shittu et al., 2007).

3.8 Optimal Drying Temperature and Time

Drying has been identified as the major tool for expanding processing of cassava into high quality cassava flour, since its moisture content is on the high side, as shown in Table 3.4. This makes it deteriorate at a fast rate once harvested.
3.8.1 Natural Drying

Local processors expose cassava mash on a polythene sheet directly to the sun. This is referred to as “sun drying”. In rural or domestic levels due to high capital investment in equipment and energy required, natural sun drying is done. Shape and size (geometry) affect drying. It takes 2 to 3 sunny days at an average temperature of 25°C to be actualized.

3.8.2 Artificial Drying

If a controllable source of energy is used for drying operations, the process is referred to as artificial or mechanical drying. Air used for drying is heated, either by solar means or controlled means such as electricity, renewable fuels or fossil fuels, with constant air velocity of 1.5 m/s. To obtain high quality cassava and soybean flour which is a function of drying time and temperature, a controllable source (flash dryer) was used. Flash dryer systems are mainly for drying moist powders, granules, crystals and wet products. The dewatered mash was fed into the feeder, it passed through the flash duct to the cyclone collector, and the drying was made possible by the heated air from the heating chamber. This is achieved by disintegrating wet cake and dried by hot gas to form dry powder. The name flash dryer originates from the fact that drying is carried out efficiently in a short span of time, usually 0.5 to 3 seconds at a temperature of 180°C, for largest particle size of 1.5 mm and particle density of 491.7 kg/m³. The principle is fairly simple, wet particulate material is entrained in hot gas or stream flowing through an insulated duct. Once the particles are dried, the gas or stream temperature decreases. In most systems, air is used as the gas. It is a well known fact that the surface area of wet lump increases as the size of lump decreases. The wet cake is disintegrated into fine sizes to increase the surface area. The drying is instantaneous and the material remains at wet bulb temperature of air. Hence it is also called as “wet bulb drying”. The air velocities are similar to that of pneumatic conveying. The powder remains suspended in air and gets conveyed while drying. Hence it is also called as pneumatic dryer. (Kuye, et al., 2007). Flash dryer was used to dry the raw materials used in this study.

3.8.3 Effects of Natural Drying

i. Slow drying rate.
ii. Contamination.
iii. Inclement weather.

Note: Minimum drying time guarantees a high quality product.
Table 3.4 Relative Composition (%) of Wheat, Cassava Root and Soybean

<table>
<thead>
<tr>
<th></th>
<th>SOY BEAN DRIED</th>
<th>SOY BEAN FRESH</th>
<th>CASSAVA ROOT DRIED</th>
<th>CASSAVA ROOT FRESH</th>
<th>WHEAT DRIED</th>
<th>WHEAT FRESH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture content</td>
<td>7.65</td>
<td>75.4</td>
<td>12.5</td>
<td>12.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ash</td>
<td>6.08</td>
<td>3.3</td>
<td>5.0</td>
<td>Nd</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Protein</td>
<td>22.75</td>
<td>Nd</td>
<td>0.85</td>
<td>Nd</td>
<td>11.0</td>
<td></td>
</tr>
<tr>
<td>Fat</td>
<td>20.38</td>
<td>1.0</td>
<td>0.7</td>
<td>1.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crude protein</td>
<td>40.65</td>
<td>2.6</td>
<td>2.0</td>
<td>12.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crude fibre</td>
<td>Nd</td>
<td>4.9</td>
<td>4.0</td>
<td>2.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soluble carbohydrate</td>
<td>0.00</td>
<td>88.2</td>
<td>75.7</td>
<td>71.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dry matter</td>
<td>Nd</td>
<td>Nd</td>
<td>87.4</td>
<td>89.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

nd → not determined

Source: (Morris, 1990).

3.9 Sensory Evaluation of Bread from Blends of Wheat/Cassava/Soybean Flours

The organoleptic evaluation of the bread loaves samples was carried out for consumer acceptance and preference using 20-trained panelist (students of the department of the Food Science and Technology, University of Nigeria, Nsukka, Nigeria). They were to evaluate the sensory properties based on Taste, Aroma, Aftertaste, Mouthfeel, Crumbcolour, Crustcolour, Texture, Appearance and Overall acceptability using a nine point Hedonic scale where 1 represents “extremely dislike” and 9 “extremely like” respectively. Means and standard errors of the mean (SEM) of scores were determined and subjected to analysis of variance (ANOVA) using the statistical package for social sciences (SPSS version 16). Means were separated using the least significant difference (LSD). As shown in Table 4.6. During sensory evaluation, panelists rinsed their mouths with water to clear the palate after each sample evaluation.

3.10 Techniques for Data Analysis, Evaluation and Optimization

3.10.1 Data Analysis

The one way analysis of variance (ANOVA) was performed to determine the significant level of all sensory attributes measured. The mean ± standard error of mean was determined for all the sensory attributes and separated by least significant difference (LSD) at $P \leq 0.05$, using Statistical Package for Social Sciences (SPSS) version 16.0 computer software.

3.10.2 Response Surface Methodology

Response surface methodology (RSM) is an effective statistical technique which has been widely used to optimize processes or formulations when many factors and their interactions may be involved. RSM was applied in this study to determine optimal temperature, time, weight, moisture content and volume on the product quality of bread baked by substituting cassava-soybean flour with wheat at different levels. (Figures 4.3 to 4.22). Contour plots are 2D graphical
outputs of RSM useful in showing how dependent variables respond to varying independent factors and identifying optimal points on a response surface. Optimization of a single response system is simple, but most practical applications involved multiple responses. A total of 50 experimental runs were conducted at various substitution levels (mix ratios). Central composite circumscribed RSM coded experimented plan was adopted and Design-Expert Software version 8 was used to determine optimal responses.

3.10.3 Residual

This is defined as the difference between the respective observed responses and their predicted model values. If a model is adequate, the points on the normal probability plots of the residuals should form a straight line. A small departure from the line in the normal probability plot is common, but a clearly “S” shaped curve indicates bimodal distribution on the residuals.

Figure 3.5 Bread from blends of wheat/cassava/soybean flours

Figure 3.6 (a) Dough from blends of wheat/cassava/soybean flours (b) Oven used for experiment
Figure 3.7 (a) Proofed dough on a weighing balance (b) Bread on an electronic weighing balance

Figure 3.8 (a) Flour samples; Cassava, Soybean and Wheat. (b) Sealed loaves awaiting analysis.

Figure 3.9 Crumb structures of breads from blends of wheat, cassava and soybean flours; samples A to F.
A= Wheat (100%); B = Wheat: Cassava + Soybean (90:10); C = Wheat: Cassava + Soybean (80:20); D = Wheat: Cassava + Soybean (70:30); E = Wheat: Cassava + Soybean (60:40); F = Wheat: Cassava + Soybean (50:50).

**Figures 3.5 to 3.9 are as follows;**

Figure 3.5 displays bread from blends of wheat/cassava/soybean flours; 3.6(a) displays kneaded dough, which was placed in a baking pan and left to rise, while time was being recorded. 3.6(b) displays picture of oven used to perform baking experiments. 3.7(a) and (b) display measurement of dough and baked loaf samples using an electronic weighing balance (model YP202N). The weight of the empty pan was recorded, then, subtracted from the weight of pan with dough content to ascertain dough’s weight. 3.8(a) and (b) display flours samples and sealed loaves awaiting analysis, Figure 3.9 displays crumb structures of bread baked at different substitution levels.

**3.11 Linear Programming Model for Cost Optimization**

This work involves optimization of a linear function subject to linear constraints. i.e., the quantity to be optimized (the objective function) is related to the variables in a linear manner. In this study, the level of production is determined by linear programming solution in order to minimize total costs. The general linear programming problem may be stated symbolically as that of optimizing the effectiveness function.

\[
\text{Minimize } W = \sum_{j=1}^{n} c_j x_j \tag{3.1}
\]

Subject to the constraints

\[
\sum_{j=1}^{n} a_{ij} x_j \geq b_i \quad i = 1,2,\ldots,m
\]

\[
X_j \geq 0 \quad j = 1,2,\ldots,n
\]
3.11.1 Mathematical Statement of Linear Programming Model

The Horizontal Approach:

\[ a_{11}x_1 + a_{12}x_2 + a_{13}x_3 + \ldots + a_{1n}x_n \geq b_1 \]
\[ a_{21}x_1 + a_{22}x_2 + a_{23}x_3 + \ldots + a_{2n}x_n \geq b_2 \]
\[ \vdots \]
\[ a_{m1}x_1 + a_{m2}x_2 + a_{m3}x_3 + \ldots + a_{mn}x_n \geq b_m \]  \hspace{1cm} (3.2)

Where all x’s must be nonnegative and each of the m equations represents a linear constraint placed upon the problem. If n is larger than m, the problem has an infinite number of solutions. However, we are interested in the optimum (minimum) solution which is given as:

\[ C_1X_1 + C_2X_2 + C_3X_3 + \ldots + C_nX_n = \text{Optimum} \]

All the rows are expressed as inequalities. The values of x variables are the solution.

3.11.2 Formulation of Optimization Algorithm

The specified indices, constants and sets are as follows;

Tasks; \( j = 1, 2, \ldots, n \)

\( C \rightarrow \) --------------------------costs of an ingredient as determined in the market.

\( X \) variables ---------------The amount (quantity) of each of the ingredients to be used.

\( a, b \) ------------------------Constants.

\( x_j \) -------------------------Vector of variables.

\( C_j \) ------------------------Vector of effectiveness coefficients.

\( a_{ij} \) -----------------------Matrix of constants .

\( b_i \) -------------------------Vector of constants.

\( x_j \geq 0 \) -------------------Since there is no physical meaning to negative production levels.

\( n \) ---------------------------Number to the nth column

\( m \) ---------------------------Number to the mth row

Source: (Maynard, 1963).
Table 3.5 Market Prices for Bakery Raw Materials and Ingredients

<table>
<thead>
<tr>
<th>Items</th>
<th>Weight (kg)</th>
<th>Prices (₦)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat flour</td>
<td>10</td>
<td>1700</td>
</tr>
<tr>
<td>Soybean flour</td>
<td>10</td>
<td>1800</td>
</tr>
<tr>
<td>Cassava flour</td>
<td>10</td>
<td>1400</td>
</tr>
<tr>
<td>Sugar</td>
<td>0.5</td>
<td>300</td>
</tr>
<tr>
<td>Butter</td>
<td>0.5</td>
<td>240</td>
</tr>
<tr>
<td>Yeast</td>
<td>0.5</td>
<td>500</td>
</tr>
<tr>
<td>Bread improver</td>
<td>0.2</td>
<td>400</td>
</tr>
<tr>
<td>Salt</td>
<td>0.5</td>
<td>50</td>
</tr>
</tbody>
</table>

The above are as obtained through market survey.

3.11.3 Method Used In Formulating Linear Programming Equation

Ingredients Cost/ Unit

Table 3.6 Cost obtained from market survey per quantity used

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>Salt</th>
<th>Sugar</th>
<th>Vitamin C (Improver)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quantity bought</td>
<td>0.5kg → ₦50</td>
<td>0.5kg → ₦300</td>
<td>0.2kg → ₦400</td>
</tr>
<tr>
<td>Quantity used</td>
<td>0.002kg → ₦x</td>
<td>0.018kg → ₦x</td>
<td>0.002kg → ₦x</td>
</tr>
<tr>
<td>Amount used;</td>
<td>x = ₦0.2K</td>
<td>x = ₦10.8K</td>
<td>x = ₦4.0K</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>Yeast</th>
<th>Butter</th>
<th>Wheat Flour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quantity bought</td>
<td>0.5kg → ₦500</td>
<td>0.5kg → ₦240</td>
<td>10kg → ₦1700</td>
</tr>
<tr>
<td>Quantity used</td>
<td>0.005kg → ₦x</td>
<td>0.008kg → ₦x</td>
<td>0.285kg → ₦x</td>
</tr>
<tr>
<td>Amount used;</td>
<td>x = ₦5.0K</td>
<td>x = ₦3.84K</td>
<td>x = ₦48.45K</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>Soybean Flour</th>
<th>Cassava Flour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quantity bought</td>
<td>10kg → ₦1800</td>
<td>10kg → ₦1400</td>
</tr>
<tr>
<td>Quantity used</td>
<td>0.285kg → ₦x</td>
<td>0.285kg → ₦x</td>
</tr>
<tr>
<td>Amount used;</td>
<td>x = ₦51.30K</td>
<td>x = ₦39.9K</td>
</tr>
</tbody>
</table>

For Composite Cassava-Soybean Mix Cost;
Quantity Used: (70% of Cassava flour) + (30% of Soybean flour)
Percent cost: (0.7 x 39.9) + (0.3 x 51.30)
Amount used; 27.93 + 15.53
= ₦ 43.32
For 90:10 Mix Ratio;
Quantity Used: \((90\% \text{ of Wheat}) + (10\% \text{ of CCS})\)
Percent cost: \((0.9 \times 48.45) + (0.1 \times 43.32)\)
Amount used: \(43.61 + 4.332 = \text{₦} 47.94\)

For 80:20 Mix Ratio;
Quantity Used: \((80\% \text{ of Wheat}) + (20\% \text{ of CCS})\)
Percent cost: \((0.8 \times 48.45) + (0.2 \times 43.32)\)
Amount used: \(38.76 + 8.664 = \text{₦} 47.424\)

For 70:30 Mix Ratio;
Quantity Used: \((70\% \text{ of Wheat}) + (30\% \text{ of CCS})\)
Percent cost: \((0.7 \times 48.45) + (0.3 \times 43.32)\)
Amount used: \(33.92 + 12.996 = \text{₦} 46.92\)

For 60:40 Mix Ratio;
Quantity Used: \((60\% \text{ of Wheat}) + (40\% \text{ of CCS})\)
Percent cost: \((0.6 \times 48.45) + (0.4 \times 43.32)\)
Amount used: \(29.07 + 17.328 = \text{₦} 46.39\)

| Table 3.7 Cost Computation per Unit Ingredient Used For Blend Formulation |
|-----------------------------|-----------------------------|-----------------------------|-----------------------------|
| Cost (₦) Used for 90:10 Mix | Cost (₦) Used for 80:20 Mix | Cost (₦) Used for 70:30 Mix | Cost (₦) Used for 60:40 Mix |
| CWCS | 47.94 | CWCS | 47.424 | CWCS | 46.92 | CWCS | 46.39 |
| Sugar | 10.8 | Sugar | 10.8 | Sugar | 10.8 | Sugar | 10.8 |
| Butter | 3.84 | Butter | 3.84 | Butter | 3.84 | Butter | 3.84 |
| Yeast | 5 | Yeast | 5 | Yeast | 5 | Yeast | 5 |
| Vit. C | 4 | Vit. C | 4 | Vit. C | 4 | Vit. C | 4 |
| Salt | 0.2 | Salt | 0.2 | Salt | 0.2 | Salt | 0.2 |
| \(\sum = 71.78\) | \(\sum = 71.26\) | \(\sum = 70.76\) | \(\sum = 70.23\) |
| \(\frac{1}{5}\) | \(\frac{1}{5}\) | \(\frac{1}{5}\) | \(\frac{1}{5}\) |
| \(\square 14.36\) | \(\square 14.25\) | \(\square 14.15\) | \(\square 14.05\) |

The objective function \(W\) was obtained using the cost per weight (g) computed in Table 3.6 and 3.7 While the constraints (Wheat and CCS cost) were obtained by multiplying the percentage used with the objective function for each variable, (Table 3.8). The values of the constraints of the linear programming equation were obtained by summation of (units baked multiplied by the cost for each variable).
3.12 Relations Used To Obtain Energy and Labour Cost

**Energy Cost:** (power rating of equipment used × Power cost per hour × baking time in hour × equipment efficiency).

**Labour Cost:** (hourly pay × baking time in hour)

Power cost per hour is ₦12 per KWh, the equipment (oven) used for baking has 70% efficiency, while power rating of oven is 1.15 KW and labour cost per hour is ₦20.83K.

### Table 3.8 Linear Programming Equation Formulation

<table>
<thead>
<tr>
<th>Samples:</th>
<th>11 Samples</th>
<th>11 Samples</th>
<th>11 Samples</th>
<th>11 Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mix ratio:</td>
<td>60:40</td>
<td>70:30</td>
<td>80:20</td>
<td>90:10</td>
</tr>
<tr>
<td>Average weight (g)</td>
<td>88.55</td>
<td>88.76</td>
<td>87.26</td>
<td>85.43</td>
</tr>
<tr>
<td>Average time (min)</td>
<td>16.56</td>
<td>16.34</td>
<td>15.32</td>
<td>13.47</td>
</tr>
</tbody>
</table>

**Objective function** \( W = 14.05x_1 + 14.15x_2 + 14.25x_3 + 14.36x_4 \)  

Subject to Constraints:

- **Wheat** \(8.43x_1 + 9.91x_2 + 11.40x_3 + 12.92x_4 \geq 469.26 \) \( \text{ii} \)
- **CCS** \(5.62x_1 + 4.25x_2 + 2.85x_3 + 1.43x_4 \geq 155.65 \) \( \text{iii} \)
- **Energy cost/hour** \(2.67x_1 + 2.63x_2 + 2.46x_3 + 2.16x_4 \geq 109.12 \) \( \text{iv} \)
- **Labour cost/hour** \(5.75x_1 + 5.67x_2 + 5.32x_3 + 4.68x_4 \geq 235.62 \) \( \text{v} \)

Where \( x_1, x_2, x_3, x_4 \geq 0 \)

Minimizing

**Objective function** - \(14.05x_1 - 14.15x_2 - 14.25x_3 - 14.36x_4 + W\)

- **Wheat** \(8.43x_1 + 9.91x_2 + 11.40x_3 + 12.92x_4 - S1 = 469.26\)
- **CCS** \(5.62x_1 + 4.25x_2 + 2.85x_3 + 1.43x_4 - S2 = 155.65\)
- **Energy cost/hour** \(2.67x_1 + 2.63x_2 + 2.46x_3 + 2.16x_4 - S3 = 109.12\)
- **Labour cost/hour** \(5.75x_1 + 5.67x_2 + 5.32x_3 + 4.68x_4 - S4 = 235.62\)
<table>
<thead>
<tr>
<th>X₁</th>
<th>X₂</th>
<th>X₃</th>
<th>X₄</th>
<th>-S₁</th>
<th>-S₂</th>
<th>-S₃</th>
<th>-S₄</th>
<th>W</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.43</td>
<td>9.91</td>
<td>11.40</td>
<td>12.92</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>469.26</td>
</tr>
<tr>
<td>5.62</td>
<td>4.25</td>
<td>2.85</td>
<td>1.43</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>155.65</td>
</tr>
<tr>
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Hence;  
\[ X_1 = \text{Production units for 60:40 mix.} \]  
\[ X_2 = \text{Production units for 70:30 mix.} \]  
\[ X_3 = \text{Production units for 80:20 mix.} \]  
\[ X_4 = \text{Production units for 90:10 mix.} \]  

The above evaluation was done using Gauss Jordan reduction technique to determine variables (x_1, \ldots, x_4) which satisfy the set of constraints in (ii) – (v) above. The results obtained are x_1 = 12.25, x_2 = 6.87, x_3 = 14.82, x_4 = 9.84 and objective function W = ₦625.11
3.13 Thermal Analysis of ‘CWCS’ Dough

The thermal conductivity, specific heat and thermal diffusivity of dough are important physical properties needed in the analysis of the heat transfer during the processing. Thermal conductivity of food is an important property used in calculations involving rate of heat transfer. In quantitative terms, this property gives the amount of heat that will be conducted per unit of time through the unit of thickness of the material if a unit temperature gradient exists across that thickness. Specific heat is a quantity of heat that is gained or lost by unit mass of product to accomplish a unit change in temperature, without a change in state. Specific heat is an essential part of the thermal analysis of food processing or of the equipment used in heating or cooling of foods. In designing food processes and processing equipment, we need numerical values for the specific heat of the food and materials to be used. Thermal diffusivity is a ratio involving thermal conductivity, density, and specific heat, it is the rate at which heat flows through a material property (dough). Predictive equations can be used to obtain values. Predictive equations are empirical expressions, obtained by fitting experimental data into mathematical models. The transfer of heat in the oven by each individual mode can be expressed in terms of temperature driving force, transfer area and heat transfer coefficient, assuming steady state heat transfer. (Bernarda et al., 2007). According to Fourier’s law of undirectional conduction steady state rate heat flow through the sample is

\[ q = \frac{k \cdot A \Delta T}{\Delta x} \text{ [W]} \]  

Where;
- \( q \) Heat flow through the material \( \text{W} \)
- \( k \) Thermal conductivity of sample \( \text{(W/m. K)} \)
- \( A \) Area surface of sample \( \text{(m}^2\text{)} \)
- \( \Delta T \) Temperature difference of the sample \( \text{K} \)
- \( \Delta x \) Thickness of sample \( \text{(m)} \)

The density of dough was determined by weighing a known volume of the dough. The thermal diffusivity can be obtained from the following equation.

\[ \alpha = \frac{k}{\rho \cdot c_p} \text{ [m}^2\text{/s]} \]
Where;

\(\alpha\)  **Thermal diffusivity** (m\(^2\)/s)

\(k\)  **Thermal conductivity coefficient** (W/m· K)

\(\rho\)  **Density** (kg/m\(^3\))

\(C_p\)  **Specific heat capacity** (J/kg· K)

The specific heat at constant volume is defined as the rate of change of specific internal energy with temperature at constant volume. The is written as

\[ C_v = \left( \frac{\partial U}{\partial T} \right)_V \]  \hspace{1cm} 3.5

Where \(\Delta U = C_v \Delta T\)

During baking of dough in oven, heat is mainly transferred:

1. By conduction to the bottom of the dough surface which is in contact with hot surface.
2. Partly by radiation to the surface of the dough exposed to air.
3. By free convection to the exposed surface of the dough.

The heat transfer between media (hot surface) and the product takes place by conduction:

\[ q_c = \frac{k A (T_h - T_i)}{x} \]  \hspace{1cm} 3.6

Where

\(k\)  **Thermal conductivity of dough** (W/m· K)

\(A\)  **Area of dough in contact with heating medium (hot surface)** (m\(^2\))

\(T_h\)  **Temperature of hot side of dough in contact with hot surface** K

\(T_i\)  **Initial temperature of dough** K

\(x\)  **Thickness of dough** (m)

\(q\)  **Heat flow through the material**  W

The heat transferred by radiation during baking of dough is expressed as

\[ q_{rad} = \varepsilon \sigma A (T_s^4 - T_{sur}^4) \]  \hspace{1cm} 3.7
Where

\[ \begin{align*} 
\epsilon & \text{ Total emissivity of the surface, } 0 \leq \epsilon \leq 1 \\
\sigma & = 5.67 \times 10^{-8} \left[ \frac{W}{m^2 \cdot K^4} \right] \text{ Stefan-Boltzmann constant} \\
T_s & \text{ Surface temperature} \\
T_{sur} & \text{ Surrounding temperature} \\
q_{rad} & > 0 \text{ if } T_s > T_{sur} \\
q_{rad} & < 0 \text{ if } T_s < T_{sur} 
\end{align*} \]

The heat transfer between air and dough takes place by free convection.

\[ q_{fc} = h_{fc} \cdot A \cdot (T_h - T_i) \]  \hspace{1cm} (3.8)

Where

\[ \begin{align*} 
h_{fc} & \text{ Heat transfer coefficient for free convection (W/m}^2 \cdot \text{K)} \\
T_h & \text{ Temperature of hot side of dough in contact with hot surface (K)} \\
T_i & \text{ Initial temperature of dough (K)} \\
A & \text{ Area of dough in contact with heating medium (hot surface) (m}^2) 
\end{align*} \]

Theoretically, total heat transferred to dough must be equal to the heat absorbed by dough. Heat transferred to dough is equal to

\[ q_t = q_c + q_{fc} \]  \hspace{1cm} (3.9)

And heat absorbed by dough is equal to

\[ q_a = q_s + q_t \]  \hspace{1cm} (3.10)

The sensible heat is given as;

\[ q_s = \frac{W \cdot C_p \cdot (T_h - T_i)}{\Delta t} \]  \hspace{1cm} [W]  \hspace{1cm} (3.11)

Where

\[ \begin{align*} 
W & \text{ Weight of dough (kg)} \\
C_p & \text{ Specific heat capacity of dough (KJ/Kg. K)} \\
T_h & \text{ Temperature of hot side of dough in contact with hot surface K} \\
T_i & \text{ Initial temperature of dough K} \\
\Delta t & \text{ Elapsed time (s)} 
\end{align*} \]
The Latent heat is given as:

\[ q_l = \frac{H_{vap} \cdot \Delta m}{\Delta t} \quad [W] \quad 3.12 \]

Where

- \( H_{vap} \)  Latent heat of vapourization of water (2256.97 KJ/Kg)
- \( \Delta m \)  Moisture mass loss of dough during baking (kg)
- \( \Delta t \)  Elapsed time (s)

To calculate the transferred heat by convection, free convection heat transfer coefficient was obtained using the Nusselt number

\[ Nu = \rho (G_r, P_r) \]

\[ Nu = a \cdot (G_r \cdot P_r)^m \]

\[ Nu = \frac{h_{fc} \cdot L}{K} \]

\[ h_{fc} = Nu \cdot \frac{K}{L} \]

Where

- \( Nu \)  Nusselt number
- \( Gr \)  Grashof number (1.42)
- \( Pr \)  Prandtl number (10^8)
- \( k \)  Thermal conductivity for air at average temperature of film (W/m. K)
- \( L \)  Length of dough (m)

The parameters \( a \) and \( m \) were obtained from literature. For \((Gr \cdot Pr)\) equal to \(10^3\), the heat transferred is approximately equal to conduction alone, but for \((Gr \cdot Pr)\) range from \(10^4\) to \(10^6\), the heat transferred is given by \( Nu = 0.15 \cdot (Gr \cdot Pr)^{0.25} \) for values of \((Gr \cdot Pr)\), \( Nu \) is proportional to \((Gr \cdot Pr)^{1/3}\), showing that the heat is transferred not entirely by convection and is not influenced by distance between the surfaces (Coulson et al., 1980).
The free convection heat transfer coefficient was obtained using the following equation

\[ h_{fc} = 0.14 \left( \text{Gr} \cdot \text{Pr} \right)^{1/3} \frac{K}{L} \]  

Specific heat capacities were determined using the various compositions of the samples.

\[ C_p = 4.180X_m + 1.711X_p + 1.929X_f + 1.547X_c + 0.908X_a \]  

(Chukwuneke et al., 2013).

Where \( C_p \) is the specific heat capacity in KJ/Kg. K and X are respective mass fractions of moisture, protein, fat, carbohydrate and ash, present in each sample.

**3.14 Process of Heat Transfer to Dough**

Heat is transmitted to the dough in three different ways:

- **i. Radiation**
- **ii. Convection caused by the turbulence of the air in the oven**
- **iii. Conduction where the dough is in contact with the heated surface either the hearth or the sides of the pan**

All three heat transmission modes play important roles in baking. Their relative importance depends on the type and the design of the oven. During the baking process, the heated internal surface of the oven emanates invisible infrared rays, which are called radiant heat. This heat is absorbed by the exposed surface of the products thus increasing their temperature. Thermal radiation is a process in which energy is emitted by a heated body in the form of electromagnetic radiation. Infrared rays travel at the speed of light directly to the point of absorption. This kind of thermal radiation represents the most complex mode of heat transmission. Convected heat is distributed through the baking chamber by the turbulence of the atmosphere and is transferred by conduction to the products when the hot air contacts their surfaces. In general, the more rapid the air movement, the more rapid and efficient the heat diffusion will be. During the baking process, the side and bottom crusts of the products absorb the heat that is transmitted by the pan walls or the stone hearth and that of the bread is called conduction. Conduction heat and radiant heat raise the temperature of the bottom and sidewalls (in case the product is baked in a pan) and then the heat is transferred into the interior of the products.
CHAPTER FOUR
4.0 RESULTS AND DISCUSSIONS

The whole idea is to investigate the possibility of integrating cassava-soy flour into wheat flour for bread baking.

4.1 Temperature

4.1.1 Constant Temperature and Varied Time

Dough proofing occurred for 45 to 50 minutes, proofed loaves were baked in oven preheated to set condition of 230°C and baking spanned for 45 to 50 minutes (Table 4.1). In the first part of this work, baking temperature was kept constant at 230°C, time was allowed to run until a desirable crust colour was observed through a show-glass on the oven for each sample experimented (i.e. varied mix blends). Mix blends (Table 3.2), were varied to check the possibility of accommodating more quantity of indigenous crops, which would greatly lower cost of production and in turn lower cost of baked foods. The optimality of temperature used was ascertained through consumer perception (sensory evaluation), as shown in Table 4.6 and displayed graphically in Figure 4.24. Acceptable breads were baked, however, decrease in acceptance was observed as substitution level increased. This is in agreement with the findings by Aluko and Olugbemi, (1989), who found lower volumes associated with composite as opposed to 100% wheat.

As an improvement on the composite flour experimented upon by (Shittu et al., 2007). Who used composite flour of cassava and wheat at 10:90 ratio, soybean flour was added in the composite flour used in this experiment at varied mix ratios to increase the protein content of loaf, thereby, improving the nutritional value of loaves baked.

4.1.2 Varied Temperature

The second phase of the experiment involved varied temperature for mix ratios; (90:10, 80:20, 70:30, and 60:40) as shown in Tables 4.2 to 4.5. A total of forty four experiments were run, which involved eleven trials for each mix ratio. Thermophysical properties (time, weight, volume, density, specific volume etc.) were measured. A central composite design was perform using Design-Expert Software to ascertain optimal values suitable for use in composite formulations.
4.2 Time

Baking time was observed to be a function of size of loaf, temperature of oven and substitution level, in both constant and varied temperature experiment. Baking time decreased as baking temperature increased at different mix ratios, while increase in baking time was observed as substitution level increased (Tables 4.2 to 4.5). Central composite design was performed to arrive at predicted optimal time for each mix ratio experimented, as shown in Tables 4.9 to 4.12.

4.3 Physical Properties of Breads from Composite Flours Blends

The effect of composite wheat, cassava and soybean flours on specific volume of bread samples is presented in Table 4.1 to 4.5. Bread specific volume decreased significantly with increasing cassava-soybean flour substitution level. The volumes of bread made from composite flours, were lower than those made from pure wheat. The highest bread specific volume was 5.03 (cm$^3$/g) for ≤ 500g, obtained from 100% wheat flour (control) while flour containing 50% cassava-soy, resulted in the lowest bread specific volume of 2.85 (cm$^3$/g), for same ≤ 500g weight of loaf. (Table 4.1). This finding is in agreement with the work reported by Aluko and Olugbemi, (1989), who found lower volumes associated with composite as opposed to 100% wheat. This can be attributed to lower levels of gluten network in the dough and consequently less ability of the dough to rise; due to the weaker cell wall structure.

Higher loaf weight and volume have positive economic effect on bread at the retail end. Therefore, loaf weight reduction during baking is an undesirable economic quality to bakers, as consumers often get attracted to bread loaf with higher weight and volume believing that it has more substance for the same price. The specific volume, which is a ratio of the loaf weight and loaf volume, has been generally adopted in literature as a more reliable measure of loaf size. Loaf volume is affected by the quantity and quality of protein in the flour (Ragaee and Abdel-Aal, 2006). As well as proofing time (Zghal et al., 2002). Whereas, loaf weight is basically determined by the quantity of dough baked, and the amount of moisture and carbon dioxide diffused out of the loaf during baking.
4.4 Moisture content

The moisture content of breads baked at set temperature 230°C for \( \leq 500\)g mix ranged from 9 to 21% (Table 4.1). And 4 to 9% for \( \leq 100\)g mix at varied temperature (Tables 4.2 to 4.5). Total absence of moisture results in very tough crumb texture which makes loaf to be undesirable, optimal moisture content becomes an important variable, since it means a better storage quality for breads baked from composite blends of wheat, cassava and soybean flour.

4.5 Mix Ratio

Mix ratio formulation affects kneading (dough preparation) and as well proofing. It was observed also that in excess of water, and or improper mixing of cassava and soybean flour, dough preparation became almost impossible, as it became sticky to both palms and kneading board. Cassava flour was mixed with soy flour at the ratio 70:30 cassava-soybean blend as shown in Table 3.1. The composite flour obtained was then mixed with whole wheat flour at various ratios (Table 3.2). In order to determine effects of thermophysical properties on mix ratios and determine optimal conditions of these properties at which products are most acceptable.

4.6 Loaf Size

The results of loaf size related parameters of the bread from composite blends are shown in Table 4.1 and 4.8. Loaf volume, weight and specific volume ranged from 1330 to 2330cm\(^3\), 460 to 468g and 2.5 to 5.1cm\(^3\)/g, respectively. A decrease in loaf volume and specific volume was observed at increased substitution level, as displayed in Figures 4.1 and 4.2. It must also be mentioned that baking temperature and time affect moisture retention capacity of bread crumb (Eggleston et al., 1993). Prolonged baking time and very high temperature resulted in tough crumb texture and undesirable crust colour.

4.7 Time – Temperature Advantage on the Product Quality of CWCS Bread

Time and temperature are the two major parameters in the process of baking. Proper adjustments to these parameters can improve greatly the quality of bread significantly. Temperature also has an impact on how loaves bake. The general rule is that crusty breads should be baked at as high a temperature as possible. Soft shelled breads should be baked at lower temperature. During baking, temperature and time work in opposition, increase in temperature of oven results in reduced baking time while decrease in baking temperature of oven results in prolonged baking time. At several experimental runs, optimal baking temperature and time were determined using response surface methodology. (Tables 4.9 to 4.12)
4.8 High Quality Cassava Flour (HQCF)

This is determined (produced) primarily by wet milling of fresh cassava roots. All equipment is made from stainless steel where it is in contact with cassava. The process consists of peeling and washing, disintegration with a high speed mechanical grater, and dewatering by mechanical means. The drying is done by a flash dryer at temperatures of at least 165 to 180 degree Celsius, milling the dried flour in an industrial pin mill to less than 200μm, cooling down the flour to ambient temperature, this is followed by sieving and packaging prior to use.

Characteristics of high quality cassava flour are;

a. At least 98% of the flour will pass a sieve of 200μm and a standard homogenous sizing for every batch.

b. All cyanide, nearly all proteins and dissolvable matter have been removed. No risk at all for public health.

c. Standard and consistent quality between all batches as regards moisture content and all other parameters. Batches do not differ or very slightly from each other.

d. Free from colour, and odour which is as a result of fermentation.

4.9 Mix Strength Determination of Dough

In dough formulation, mix blend becomes an important aspect. Different trials at various ratios were conducted. It was observed that some mix formulations behaved as follows;

a. Tend to form a skin.

b. Firm up very quickly.

c. Less elastic.

d. Get sticky.

e. Mature slowly or remain young for a long time.

While at a mix of 70% cassava and 30% soy flour inclusion to wheat at 0%, 10%, 20%, 30%, 40% and 50% gave a moderate flow of dough, matured optimally and didn’t stick to either hand or kneading board. In addition, the plastic limit test is useful in determining the mix strength of dough.

4.10 Thermal Computations

Specific heat capacities were determined using the various compositions of the samples. (Table 3.4)

\[ C_p = 4.180Xm + 1.711Xp + 1.929Xf + 1.547Xc + 0.908Xa \]

Where \( C_p \) is the specific heat capacity in KJ/Kg. K and X are respective mass fractions of moisture, protein, fat, carbohydrate and ash, present in each sample.
From equation 3.14, the following values were determined:

\[ C_p \text{ for soy flour} = 115.74 \text{ Kj/Kg. K} \]
\[ C_p \text{ for wheat flour} = 182.09 \text{ Kj/Kg. K} \]
\[ C_p \text{ for cassava flour} = 176.70 \text{ Kj/Kg. K} \]

\[
\sum C_p \text{ for composite blend} = 474.53 \text{ Kj/Kg. K}
\]

Thermal conductivity \( k \) was obtained from literature (Bernarda et al., 2007) for average value of dough as 0.476 W/m. K

- Average thickness of dough: 0.13m
- Average baking temperature of dough: 220°C
- Ambient temperature of dough: 32°C
- Area of dough: 0.013273 m²
- Average weight of loaf: 0.0854 Kg
- Average volume of loaf: 0.000707 m³
- Average density of loaf: 120.86 Kg/m³
- Average time of baking: 903.6 s

From equation 3.13, \( h_{fc} \) is given as

\[
h_{fc} = 0.14 \times (1.42 \times 10^8)^{1/3} \times \frac{0.027375}{0.13}
\]

\[
= 68.61 \times 0.2106
\]

\[
= 14.45 \text{ W/m. K}
\]

From equation 3.6, \( q_c \) is given as

\[
q_c = \frac{0.476 \times 0.013273 \times 461.15}{0.13}
\]

\[
= 88.45 \text{ W}
\]

From equation 3.8, \( q_{fc} \) is given as

\[
q_{fc} = 14.45 \times 0.013273 \times 461.15
\]

\[
= 88.45 \text{ W}
\]
Total heat transferred to single dough is equal to heat transferred by conduction and by free convection (neglecting heat transferred by radiation)

From equation 3.9, $q_t$ was obtained

$$q_t = 22.41 + 88.45$$

$$q_t = 110.86\,\text{W}$$

The total heat absorbed by the product is calculated from equation …

$$q_a = q_s + q_l$$

From equation 3.11, $q_s$ was given as;

$$q_s = \frac{0.0854 \cdot 474.53 \cdot 461.15}{903.6}$$

$$q_s = 20.68\,\text{W}$$

From equation 3.12, $q_l$ is given as;

$$q_l = \frac{2256.97 \cdot 1000 \cdot 0.008869}{903.6}$$

$$q_l = 22.15\,\text{W}$$

From equation 3.10, $q_a$ is given as;

$$q_a = 20.68 + 22.15$$

$$q_a = 42.83\,\text{W}$$

Thermal diffusivity is given from equation 3.4 as

$$\alpha = \frac{0.476}{120.859 \times 474.53}$$

$$\alpha = 8.2997 \times 10^{-6}\,\text{m}^2/\text{s}$$
Data Presentation

Table 4.1 Thermophysical Properties of Bread from Blends of Composite Flours at Set Temperature

<table>
<thead>
<tr>
<th>Sample</th>
<th>Dough Proofing time (mins)</th>
<th>Baking Time (mins)</th>
<th>Baking Temp. °C</th>
<th>MC %</th>
<th>Mix ratio w:ccs</th>
<th>Weight of Dough (g)</th>
<th>Weight of Bread (g)</th>
<th>Loaf Volume Cm³</th>
<th>Specific Volume (Cm³/g)</th>
<th>Density g/Cm³</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>45.00</td>
<td>45.00</td>
<td>230.00</td>
<td>20.60</td>
<td>100:00</td>
<td>482.80</td>
<td>462.20</td>
<td>2323</td>
<td>5.03</td>
<td>0.199</td>
</tr>
<tr>
<td>B</td>
<td>46.20</td>
<td>47.50</td>
<td>230.00</td>
<td>09.50</td>
<td>90:10</td>
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<td>461.90</td>
<td>2105</td>
<td>4.56</td>
<td>0.219</td>
</tr>
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<td>47.57</td>
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<td>465.70</td>
<td>1984</td>
<td>4.26</td>
<td>0.235</td>
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<tr>
<td>D</td>
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<td>48.20</td>
<td>230.00</td>
<td>12.50</td>
<td>70:30</td>
<td>479.20</td>
<td>466.70</td>
<td>1815</td>
<td>3.89</td>
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</tr>
<tr>
<td>E</td>
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<td>48.54</td>
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<td>60:40</td>
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<td>1621</td>
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<td>F</td>
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<td>49.33</td>
<td>230.00</td>
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<td>50:50</td>
<td>485.60</td>
<td>467.50</td>
<td>1331</td>
<td>2.85</td>
<td>0.351</td>
</tr>
</tbody>
</table>

A = wheat (100%), B = [wheat (90%) + [cassava + soybean (10%)], C = [wheat (80%) + [cassava + soybean (20%)], D = [wheat (70%) + [cassava + soybean (30%)], E = [wheat (60%) + [cassava + soybean (40%)], F = [wheat (50%) + [cassava + soybean (50%)] MC = Moisture content.
Table 4.2 Thermophysical Properties of Bread from Blends of Composite Flours for 90:10 Mix at Temperature Range of 195 to 245°C

<table>
<thead>
<tr>
<th>Temp. °C</th>
<th>Baking Time (min)</th>
<th>Proofing Time (min)</th>
<th>Weight of Dough (g)</th>
<th>Weight of Loaf (g)</th>
<th>Moisture Content %</th>
<th>Area of pan cm²</th>
<th>Volume of Loaf cm³</th>
<th>Specific volume cm³/g</th>
<th>Density g/cm³</th>
<th>Mix ratio</th>
<th>Durability Shelf life (days)</th>
<th>Plastic Limit Test (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>195</td>
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<td>85.90</td>
<td>8.00</td>
<td>132.73</td>
<td>676.92</td>
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<td>0.126</td>
<td>90:10</td>
<td>4.00</td>
<td>0.21</td>
</tr>
<tr>
<td>200</td>
<td>16.55</td>
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<td>84.40</td>
<td>8.00</td>
<td>132.73</td>
<td>683.56</td>
<td>8.09</td>
<td>0.123</td>
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<tr>
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<td>94.50</td>
<td>85.80</td>
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<td>132.73</td>
<td>703.47</td>
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<td>4.00</td>
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<td>210</td>
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<td>132.73</td>
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<td>84.50</td>
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<td>703.47</td>
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<td>87.10</td>
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<td>132.73</td>
<td>690.19</td>
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</table>
Table 4.3 Thermophysical Properties of Bread from Blends of Composite Flours for 80:20 Mix at Temperature Range of 195 to 245°C

<table>
<thead>
<tr>
<th>Temp. °C</th>
<th>Baking Time (min)</th>
<th>Proofing Time (min)</th>
<th>Weight of Dough (g)</th>
<th>Weight of Loaf (g)</th>
<th>Moisture Content %</th>
<th>Area of pan cm²</th>
<th>Volume of Loaf cm³</th>
<th>Specific volume cm³/g</th>
<th>Density g/cm³</th>
<th>Mix ratio</th>
<th>Durability Shelf life (days)</th>
<th>Plastic Limit Test (cm)</th>
</tr>
</thead>
<tbody>
<tr>
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<td>0.149</td>
<td>80:20</td>
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</table>
Table 4.4 Thermophysical Properties of Bread from Blends of Composite Flours for 70:30 Mix at Temperature Range of 195 to 245°C

<table>
<thead>
<tr>
<th>Temp. °C</th>
<th>Baking Time (min)</th>
<th>Proofing Time (min)</th>
<th>Weight of Dough (g)</th>
<th>Weight of Loaf (g)</th>
<th>Moisture Content %</th>
<th>Area of pan cm²</th>
<th>Volume of Loaf cm³</th>
<th>Specific volume cm³/g</th>
<th>Mix ratio</th>
<th>Durability Shelf life (days)</th>
<th>Plastic Limit Test (cm)</th>
<th>Density g/cm³</th>
</tr>
</thead>
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<td>0.146</td>
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<td>132.73</td>
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<td>90.60</td>
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</table>
Table 4.5 Thermophysical Properties of Bread from Blends of Composite Flours for 60:40 Mix at Temperature Range of 195 to 245°C

<table>
<thead>
<tr>
<th>Temp. °C</th>
<th>Baking Time (min)</th>
<th>Proofing Time (min)</th>
<th>Weight of Dough (g)</th>
<th>Weight of Loaf (g)</th>
<th>Moisture Content %</th>
<th>Area of pan cm²</th>
<th>Volume of Loaf cm³</th>
<th>Specific volume cm³/g</th>
<th>Density g/cm³</th>
<th>Mix ratio</th>
<th>Durability Shelf life (days)</th>
<th>Plastic Limit Test (cm)</th>
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Table 4.6 Sensory Scores of Bread from Blends of Wheat/Cassava/Soybean Flour

<table>
<thead>
<tr>
<th>BREAD SAMPLES</th>
<th>TASTE</th>
<th>AFTER TASTE</th>
<th>AROMA</th>
<th>CRUST COLOUR</th>
<th>CRUMB COLOUR</th>
<th>MOUTH FEEL</th>
<th>TEXTURE</th>
<th>APPEARANCE</th>
<th>OVERALL ACCEPTABILITY</th>
<th>AVERAGE ASSESSMENT</th>
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<tr>
<td></td>
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<td>Mean ± SEM</td>
<td>Mean ± SEM</td>
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<td>Mean ± SEM</td>
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</tr>
<tr>
<td>A</td>
<td>7.25 ± 0.22^a</td>
<td>7.30 ± 0.27^a</td>
<td>7.80 ± 0.25^a</td>
<td>8.45 ± 0.14^a</td>
<td>8.55 ± 0.17^a</td>
<td>7.40 ± 0.27^b</td>
<td>7.80 ± 0.20^b</td>
<td>8.25 ± 0.23^c</td>
<td>7.90 ± 0.23^a</td>
<td>7.86 ± 0.15^a</td>
</tr>
<tr>
<td>B</td>
<td>6.55 ± 0.31^ab</td>
<td>6.55 ± 0.30^b</td>
<td>7.05 ± 0.35^b</td>
<td>8.10 ± 0.24^a</td>
<td>8.20 ± 0.20^c</td>
<td>7.15 ± 0.17^d</td>
<td>7.40 ± 0.20^e</td>
<td>7.35 ± 0.24^b</td>
<td>7.45 ± 0.18^a</td>
<td>7.31 ± 0.18^b</td>
</tr>
<tr>
<td>C</td>
<td>6.25 ± 0.31^b</td>
<td>6.40 ± 0.30^b</td>
<td>6.95 ± 0.28^bc</td>
<td>7.75 ± 0.35^ab</td>
<td>7.50 ± 0.30^bc</td>
<td>6.90 ± 0.22^ab</td>
<td>7.05 ± 0.26^c</td>
<td>6.85 ± 0.30^bc</td>
<td>6.70 ± 0.30^bc</td>
<td>6.93 ± 0.23^bc</td>
</tr>
<tr>
<td>D</td>
<td>5.85 ± 0.24^bd</td>
<td>5.55 ± 0.18^c</td>
<td>6.70 ± 0.21^bd</td>
<td>7.30 ± 0.24^b</td>
<td>7.25 ± 0.23^b</td>
<td>7.50 ± 0.20^bc</td>
<td>6.20 ± 0.22^b</td>
<td>6.50 ± 0.22^cd</td>
<td>6.20 ± 0.16^cd</td>
<td>6.42 ± 0.12^f</td>
</tr>
<tr>
<td>E</td>
<td>5.25 ± 0.24^cd</td>
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<td>7.35 ± 0.29^b</td>
<td>7.10 ± 0.32^b</td>
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<td>6.00 ± 0.35^b</td>
<td>5.85 ± 0.32^de</td>
<td>5.80 ± 0.30^d</td>
<td>6.15 ± 0.21^cd</td>
</tr>
<tr>
<td>F</td>
<td>5.35 ± 0.21^cd</td>
<td>4.85 ± 0.22^c</td>
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<td>6.95 ± 0.26^d</td>
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<td>5.10 ± 0.39^f</td>
<td>5.55 ± 0.34^e</td>
<td>4.85 ± 0.33^e</td>
<td>5.69 ± 0.21^d</td>
</tr>
</tbody>
</table>

SEM = Standard error of mean. Values with different superscripts on the same column mean significant difference at P<0.05

A = wheat (100%), B = [wheat (90%)] + [cassava + soybean (10%)], C = [wheat (80%)] + [cassava + soybean (20%)], D = [wheat (70%)] + [cassava + soybean (30%)], E = [wheat (60%)] + [cassava + soybean (40%)], F = [wheat (50%)] + [cassava + soybean (50%)]

Table 4.7 Effect of Moisture Content on Dough Plasticity of Composite Wheat, Cassava and Soybean Mix

<table>
<thead>
<tr>
<th>MC %</th>
<th>PLT (cm) Ø</th>
<th>PLT (cm) r</th>
<th>CSA πr² (cm²)</th>
<th>MC %</th>
<th>PLT (cm) Ø</th>
<th>PLT (cm) r</th>
<th>CSA πr² (cm²)</th>
<th>MC %</th>
<th>PLT (cm) Ø</th>
<th>PLT (cm) r</th>
<th>CSA πr² (cm²)</th>
<th>MC %</th>
<th>PLT (cm) Ø</th>
<th>PLT (cm) r</th>
<th>CSA πr² (cm²)</th>
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<td>0.0346</td>
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<td>0.055</td>
<td>0.0095</td>
<td>6.1</td>
<td>0.05</td>
<td>0.025</td>
<td>0.0019</td>
<td>5.2</td>
<td>0.11</td>
<td>0.055</td>
<td>0.0095</td>
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<td>0.05</td>
<td>0.025</td>
<td>0.0019</td>
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<td>0.12</td>
<td>0.060</td>
<td>0.0113</td>
<td>5.1</td>
<td>0.15</td>
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<td>0.0177</td>
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<td>0.055</td>
<td>0.0095</td>
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<td>0.100</td>
<td>0.0314</td>
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<td>0.100</td>
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<td>0.105</td>
<td>0.0346</td>
<td>6.2</td>
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[MC=Moisture Content, PLT=Plastic limit test, CSA=Cross sectional area.]
Table 4.8 Physical Properties of Bread Samples

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<tr>
<th>Sample</th>
<th>Length (L) of pan (cm)</th>
<th>Width (W) of pan (cm)</th>
<th>Height (H) of Loaf (cm)</th>
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<tbody>
<tr>
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<tr>
<td>B</td>
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<td>6.7</td>
</tr>
<tr>
<td>F</td>
<td>22</td>
<td>11</td>
<td>5.5</td>
</tr>
</tbody>
</table>

A= wheat (100%), B = [wheat (90%) + [cassava + soybean (10%)], C = [wheat (80%) + [cassava + soybean (20%)], D = [wheat (70%) + [cassava + soybean (30%)], E = [wheat (60%) + [cassava + soybean (40%)], F = [wheat (50%) + [cassava + soybean (50%)]]

Figure 4.1 Specific Volume and Density of Formulated Bread Samples from Blends of Wheat/Cassava/Soybean.

A= wheat (100%), B = [wheat (90%) + [cassava + soybean (10%)], C = [wheat (80%) + [cassava + soybean (20%)], D = [wheat (70%) + [cassava + soybean (30%)], E = [wheat (60%) + [cassava + soybean (40%)], F = [wheat (50%) + [cassava + soybean (50%)]]
Figure 4.2 Variation in Height(Cm) of Bread Samples from Blends of Wheat/Cassav/Soybean.

A= wheat (100%), B = [wheat (90%)] + [cassava + soybean (10%)], C = [wheat (80%)] + [cassava + soybean (20%)], D = [wheat (70%)] + [cassava + soybean (30%)], E = [wheat (60%)] + [cassava + soybean (40%)], F = [wheat (50%)] + [cassava + soybean (50%)]

4.12 Central Composite Designs of Response Surface Methodology

Mixture Ratio: 90:10. Response 1: weight
Figure 4.3 Central composite design for optimal weight (85.4538g) for ≤ 100g mix at 90:10 mix ratio

**Response 2, moisture**

Figure 4.4 Central composite design for optimal moisture (8.86923%) for ≤ 100g mix at 90:10 mix ratio
Figure 4.5 Combined effect of temperature and time on the moisture content (8.86923%) at 90:10 mix ratio

Response 3, volume

Figure 4.6 Central composite design for optimal volume (707.145cm$^3$) for $\leq$ 100g mix at 90:10 mix ratio
Figure 4.7 Combined effect of temperature and time on volume (707.145 cm$^3$) at 90:10 mix ratio

Table 4.9 Response surface prediction summary on optimal variables at 90:10 mix ratio for ≤ 100g mix

It is observed that the population distribution function (Figures 4.3, 4.4 and 4.6) follows normal distribution implying that there is no much departure from the mean.
Mixture Ratio: 80:20, Response 1, weight

Figure 4.8 Central composite design for optimal weight (87.2015g) for ≤ 100g mix at 80:20 mix ratio

Response 2, moisture

Figure 4.9 Central composite design for optimal moisture (6.46%) for ≤ 100g mix at 80:20 mix ratio
Figure 4.10 Combined effect of temperature and time on the moisture content (6.46%) at 80:20 mix ratio

**Response 3, volume**

Figure 4.11 Central composite design for optimal volume (624.853cm$^3$) for ≤ 100g mix at 80:20 mix ratio
Table 4.10 Response surface prediction summary on optimal variables at 80:20 mix ratio for ≤ 100g mix

<table>
<thead>
<tr>
<th>Factor</th>
<th>Name</th>
<th>Level</th>
<th>Low Level</th>
<th>High Level</th>
<th>Std. Dev.</th>
<th>Coding</th>
</tr>
</thead>
<tbody>
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<td>A</td>
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<td>Actual</td>
</tr>
<tr>
<td>B</td>
<td>Time</td>
<td>16.33</td>
<td>10.46</td>
<td>22.19</td>
<td>0.000</td>
<td>Actual</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Response</th>
<th>Prediction</th>
<th>Std Dev</th>
<th>SE (n=1)</th>
<th>95% PI low</th>
<th>95% PI high</th>
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<tr>
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<td>87.2015</td>
<td>1.04723</td>
<td>1.08676</td>
<td>84.8337</td>
<td>89.5694</td>
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<td>moisture</td>
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<td>0.841573</td>
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<tr>
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<td>624.853</td>
<td>34.8899</td>
<td>36.207</td>
<td>545.965</td>
<td>703.741</td>
</tr>
</tbody>
</table>

It is observed that the population distribution function (Figures 4.8, 4.9 and 4.11) follows normal distribution implying that there is no much departure from the mean.

**Mixture Ratio : 70:30, Response 1, weight**

![Normal Plot of Residuals](image)

Figure 4.12 Central composite design for optimal weight (94.961g) for ≤ 100g mix at 70:30 mix ratio
Response 2, Moisture

Figure 4.13 Central composite design for optimal moisture (6.06%) for ≤ 100g mix at 70:30 mix ratio

Figure 4.14 Combined effect of temperature and time on the moisture content (6.06%) at 70:30 mix ratio
Response 3, Volume

Figure 4.15 Central composite design for optimal volume (573.804cm$^3$) for $\leq$ 100g mix at 70:30 mix ratio

Figure 4.16 Combined effect of temperature and time on volume (573.804cm$^3$) at 70:30 mix ratio
Table 4.11 Response surface prediction summary on optimal variables at 70:30 mix ratio for ≤ 100g mix

<table>
<thead>
<tr>
<th>Factor</th>
<th>Name</th>
<th>Level</th>
<th>Low Level</th>
<th>High Level</th>
<th>Std. Dev.</th>
<th>Coding</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
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<td>245.00</td>
<td>0.000</td>
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</tr>
<tr>
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<td>23.21</td>
<td>0.000</td>
<td>Actual</td>
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</table>

<table>
<thead>
<tr>
<th>Response</th>
<th>Prediction</th>
<th>Std Dev</th>
<th>SE (n=1)</th>
<th>95% PI low</th>
<th>95% PI high</th>
</tr>
</thead>
<tbody>
<tr>
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<td>22.1268</td>
<td>524.502</td>
<td>623.105</td>
</tr>
</tbody>
</table>

It is observed that the population distribution function (Figures 4.12, 4.13 and 4.15) follows normal distribution implying that there is no much departure from the mean.

**Mixture Ratio: 60:40 Response 1, Weight**

![Normal Plot of Residuals](image)

Figure 4.17 Central composite design for optimal weight (87.4g) for ≤ 100g mix at 60:40 mix ratio
Figure 4.18 Combined effect of temperature and time on weight (87.4g) at 60:40 mix ratio

Response 2, Moisture

Figure 4.19 Central composite design for optimal moisture (7.12%) for ≤ 100g mix at 60:40 mix ratio
Figure 4.20 Combined effect of temperature and time on moisture (7.12%) at 60:40 mix ratio

Response 3, Volume

Figure 4.21 Central composite design for optimal volume (558.181 cm³) for ≤ 100g mix at 60:40 mix ratio
Figure 4.22 Combined effect of temperature and time on volume (558.181cm³) at 60:40 mix ratio

Table 4.12 Response surface prediction summary on optimal variables at 60:40 mix ratio for ≤ 100g mix.

It is observed that the population distribution function (Figures 4.17, 4.19 and 4.21) follows normal distribution implying that there is no much departure from the mean.
Description of Normal Plots of Residuals

The normal probability plot of residuals is a graphical tool in checking the normality assumption. The normality assumption indicates that continuous data of the kind used in this study must be normally distributed. If the residuals plot is approximately along a straight, the normality assumption is satisfied. Figures 4.3, 4.4, 4.6, 4.8, 4.9, 4.11, 4.12, 4.13, 4.15, 4.17, 4.19 and 4.21 are the respective normal probability plots for the various response variables at different mix ratios. The concentration (or clustering) of the points along the straight lines indicates that the normality assumption is satisfied for the different data sets for the different mix ratios.

Description of Contour Plots

Contour plot is a two–dimensional topographical map involving data on three variables. The horizontal and vertical axes represent the two independent variables which the third variable is represented by lines of constant values. The lines of the third variable (response) correspond to the values of the two independent variables. Contour plots are useful in data analysis, especially when searching for the optimal combination of the independent variables that give optimal response (yield). The predicted optimal responses are indicated (flagged) in the contour plots.

The contour lines in figures 4.5, 4.7, 4.10, 4.14, 4.16, 4.18, 4.20 and 4.22 are curves simply indicating strong interactions between the independent variables, time and temperature in predicting optimal response (of the dependent variable). Irrespective of the nature of the curve, either elliptical as in figure 4.20 or spherical as in figure 4.5, the curvature strongly indicates the reason why second-order response surface model is adequate in fitting the CCD (common core of data).

The contour lines in figures 4.16, 4.18 and 4.22 are straight lines indicating no interaction between time and temperature in predicting optimal response for the various mix ratios and for each of the response variables.
4.13 Effects of Central Composite Design Optimality on Different Mix Ratios

Central composite design shows confidence, prediction and tolerance intervals (CI, PI & TI) plotted with configurable colours in one-factor response plots: convey prediction through bands around the best fit (Figures 4.3 to 4.22). The plots show actual run result represented as a circle. The solid line is the predicted value based on the linear model. The bands are the confidence interval (narrowest), significant at $p \leq 0.05$, prediction and tolerance intervals (widest).

4.13.1 Observations

Whole wheat was mixed with cassava-soybean flour at various mix ratios, baking temperature ranged from 195 to 245°C while time, volume, weight, specific volume etc. were measured as experiment progressed. Data collected were subjected to analysis using Design-Expert Software, version 8 to obtain optimal values for each mix ratio and hence, reach conclusions. At 95% confidence level (i.e. $p \leq 0.05$), we deduced that for;

i. **90:10 Mix Ratio**

At this mix ratio, for less than or equal to 100g mix, the optimal baking temperature and time are $220^\circ$C and 15.06 minutes respectively (control variables), while dependent variables; weight, moisture content and volume are 85.4538g, 8.86923% and 707.145 cm$^3$ respectively (Table 4.9).

ii. **80:20 Mix Ratio**

At this mix ratio, for less than or equal to 100g mix, the optimal baking temperature and time are $220^\circ$C and 16.33 minutes respectively (control variables), while dependent variables; weight, moisture content and volume are 87.2015g, 6.46% and 624.853cm$^3$ respectively (Table 4.10).

iii. **70:30 Mix Ratio**

At this mix ratio, for less than or equal to 100g mix, the optimal baking temperature and time are $222.50^\circ$C and 17.16 minutes respectively (control variables), while dependent variables; weight, moisture content and volume are 94.9615g, 6.06% and 573.804cm$^3$ respectively (Table 4.11).
iv. **60:40 Mix Ratio**

At this mix ratio, for less than or equal to 100g mix, the optimal baking temperature and time are 222.50°C and 17.35 minutes respectively (control variables), while dependent variables; weight, moisture content and volume are 87.4g, 7.12% and 558.181cm³ respectively (Table 4.12).

It was observed that as substitution level increased, baking time increased, while loaf volume decreased (Tables 4.9 to 4.12). This is affected by the quantity and quality of protein in the mix (Ragaee and Abdel-Aal, 2006). This is also in agreement with the work by Aluko and Olugbemi, (1989), who found lower volumes associated with composite as opposed to 100% wheat. Variation in weight is attributed to varying stress applied during kneading.

In conclusion, the following optimal values would help in easy integration of indigenous composite flours into bread baking in Nigeria.

### 4.14 Economy of Scale of Composite Wheat, Cassava and Soybean Bread Production

One of the objectives of this research is to minimize cost of resource utilization for composite wheat, cassava and soybean bread production. To achieve this, linear programming model was used to optimize (cost minimization) production cost, to make bread accessible at an affordable cost by the majority of Nigerians, not compromising quality and quantity. Cost as obtained through market survey (Table 3.5), was formulated into linear programming equation (Table 3.8), and evaluated using Guass Jordan reduction technique to determine variables (Table 3.8). For forty four units experimented, the minimum amount (objective function W) of ₦625.11 was utilized, this means that a loaf of ≤ 100g from composite flours costs about ₦14.21k, (production cost).
4.15 Plastic Limit Test

The experimental results (Table 4.7) for moisture content versus cross sectional area in obtaining the plasticity of dough from blends of composite flours, are displayed graphically in Figures 4.23 a,b,c, and d. The charts show the effect of moisture content in dough formation, the plasticity of the dough is an indication of proper mixing and blending of mix at optimal ratio. This tells the need for bakers to ascertain the optimal moisture requirement during mix of any weight to ensure proper dough formation and as well as enhanced kneading.
Figure 4.24 Sensory Scores of Bread Samples from Blends of Wheat/Cassava/Soybean.

A = wheat (100%), B = [wheat (90%) + [cassava + soybean (10%)], C = [wheat (80%) + [cassava + soybean (20%)], D = [wheat (70%) + [cassava + soybean (30%)], E = [wheat (60%) + [cassava + soybean (40%)], F = [wheat (50%) + [cassava + soybean (50%)]]
4.16 Sensory Evaluation of Bread Samples

The sensory scores of bread samples baked from blends of wheat, cassava and soybean flour as well as the 100% wheat bread are presented in (Table 4.6) and displayed graphically in Figure 4.24. All bread samples on average assessment showed that “B” is significantly different from “A”, “C” is not significantly different from “B”, “D” and “E”, “E” is not significantly different from “C” & “D” and lastly, “F” is significantly different from all except “E”. All bread samples were rated as acceptable by the panel, overall acceptance scores indicated as follows; A=7.86, B=7.31, C=6.93, D=6.42, E=6.15 and F=5.69. Although, all samples were rated above average, the preference however, decreased as the substitution level of cassava and soybean flour increased. In this study, overall bread quality at the different levels of substitution was found to be acceptable. However, acceptability decreased as the level of cassava and soybean flour increased. These results are in agreement with the work by Kyomugisha (2002). Who found decrease in acceptability of breads made from blends of composite flour.

4.17 Contributions to Knowledge

In the course of this research;

i. Through experiment and consumers’ perception, increased substitution level to 50% non wheat inclusion to bread baking in Nigeria was achieved.

ii. Linear programming model was used to minimize cost of production which is of great benefit to consumers.

iii. Response Surface Methodology was used to predict optimal variables; temperature, time, moisture content, weight and volume at various mix ratios.

iv. Plastic limit test on dough of different substitution level was conducted as quick measure of plastic behavior of the dough and to estimate extent of moisture content.

v. This serves as a bold step towards food security and national economy boost in Nigeria.

vi. The formulation of cassava-soy and wheat composite flour results in value added product bread.

vii. The use of plastic limit test was introduced to determine mix strength in addition to the traditional trial and error method.
CHAPTER FIVE
5.0 COST ESTIMATE FOR SETTING UP A CWCS BAKERY IN NIGERIA

5.1 Cost Requirements for Setting up a CWCS Bakery in Nigeria

Bread business is a very lucrative business and the return on investment is guaranteed even under few months. Although, it is capital intensive to a beginner who does not have the required equipment and materials needed to start the business. This simply means you will have to buy/acquire the equipment such as Oven, Mixing Machine, Milling Machine, Slicing Machine, Delivery Van, Landed Property etc. But to those that have some of the required equipment, the needed capital will be reduced. To this end, there are two ways to starting this business as a beginner;

i. Rent a bakery fully loaded with the required equipment.

ii. Build and equip a new bakery to the required standard.

The following are a necessity in setting up the above mentioned bakery;

i. **Location**: This involves acquiring a landed property to site the bakery. Access to market and road becomes a vital consideration.

ii. **Equipment**: This involves all devices needed to bake bread, such as Oven, Mixing Machine, Milling Machine, Slicing Machine, generator, pan, wracks, weighing balance, cutting table, mixing bowl, Delivery Van etc.

iii. **Legal Issues**: This involves registration with regulatory bodies like The Masters Bakers Association and the NAFDAC.

iv. **Ingredients**: This requires materials needed to formulate dough; prices vary from place to place.

v. **Advertisement**: Advertisement becomes very necessary to create awareness to the people who are the targeted market.

vi. **Labour**: A vital area that has to do with staff who run managerial, production, and distribution related issues.
5.2 Break-Even Analysis

Break-even analysis tells the point at which the producer would recover all he inputted into the venture and hence, begin to make profit. Once a producer realizes the amount he spent in a commodity, he has broken-even.

Break-even analysis is given mathematically;

Sales revenue – Fixed cost – Variable cost = Net income

\[ SP(x) - FC - VC(x) = NI \]  

Where;

\[ NI = 0 \] for Break-even
SP → Selling price

FC → Fixed cost

VC → Variable cost

NI → Net income (Profit or loss)

X → Number of units sold

Hence, if a company sells one unit of its product for ₦R, the total fixed cost being ₦P and variable cost per unit is ₦Q. To determine the breakeven point; (i.e. how many units to be sold to break-even)

\[ R(x) - P - Q(x) = 0 \]

\[ (R-Q)x = P \]

\[ X = \frac{P}{R-Q} \text{ Units} \]

Hence, the value of x would be produced to break-even.

The following report represents the proposal for the establishment of a bakery that would produce (bake) breads using composite flours (wheat, cassava and soy). The proposed project is to be fully implemented with an investment of ₦7607636 as listed below;

<table>
<thead>
<tr>
<th>Table 5.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
</tr>
<tr>
<td>Legal Issues (NAFDAC, CAC)</td>
</tr>
<tr>
<td>Advertisement (Bill boards, flyers, newspapers radio, TV etc.)</td>
</tr>
<tr>
<td>Labour (Staffing i.e. monthly)</td>
</tr>
<tr>
<td>Equipment</td>
</tr>
<tr>
<td>Products (monthly)</td>
</tr>
<tr>
<td>Miscellaneous</td>
</tr>
</tbody>
</table>
Table 5.2
Monthly Payroll for Staff

<table>
<thead>
<tr>
<th>No.</th>
<th>Position</th>
<th>Rate</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Manager</td>
<td>40,000</td>
<td>40,000</td>
</tr>
<tr>
<td>2</td>
<td>Drivers</td>
<td>15,000</td>
<td>30,000</td>
</tr>
<tr>
<td>2</td>
<td>Cashiers</td>
<td>13,000</td>
<td>26,000</td>
</tr>
<tr>
<td>10</td>
<td>Bakers</td>
<td>15,000</td>
<td>150,000</td>
</tr>
<tr>
<td>4</td>
<td>Supplier</td>
<td>12,000</td>
<td>48,000</td>
</tr>
<tr>
<td>1</td>
<td>Technician</td>
<td>30,000</td>
<td>30,000</td>
</tr>
<tr>
<td>1</td>
<td>Security</td>
<td>10,000</td>
<td>10,000</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td></td>
<td>334,000</td>
</tr>
</tbody>
</table>

Table 5.3
Cost Estimate for Equipment

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mixer</td>
<td>225,000</td>
</tr>
<tr>
<td>Oven (32 trays capacity)</td>
<td>900,000</td>
</tr>
<tr>
<td>Knives and Cutters</td>
<td>5,000</td>
</tr>
<tr>
<td>Refrigerator</td>
<td>90,000</td>
</tr>
<tr>
<td>Generator</td>
<td>200,000</td>
</tr>
<tr>
<td>Stove</td>
<td>8,000</td>
</tr>
<tr>
<td>Display stands</td>
<td>85,000</td>
</tr>
<tr>
<td>Bread slicer</td>
<td>3,300</td>
</tr>
<tr>
<td>Van (2)</td>
<td>2,000,000</td>
</tr>
<tr>
<td>Trays (32)</td>
<td>42,336</td>
</tr>
</tbody>
</table>

Table 5.4
Total Capital Needed

<table>
<thead>
<tr>
<th>Capital Type</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed capital</td>
<td>6,267,636</td>
</tr>
<tr>
<td>Variable capital</td>
<td>1,340,000</td>
</tr>
<tr>
<td>Total</td>
<td>7,607,636</td>
</tr>
</tbody>
</table>

At a production rate of five hundred loaves (500g) per day, i.e. twelve thousand loaves per month, i.e. twenty four working days. At a selling price of two hundred naira per loaf, the company would break-even at a certain production as computed below;

\[
\frac{\text{Variable cost per month}}{\text{Production rate per month}} = \frac{1,340,000}{12,000} = 111.67
\]
SP(x) – FC – VC(x) = NI

200x – 6,267,636 – 111.67x = 0

88.33x = 6,267,636

X = 70,957 units

This implies that at approximately six months production, the company will break-even, i.e. fall into profit region.

5.3 Return on Investment

If the company invests 7,607,636 on this project, to give an annual dividend of 1,879,209.5 for 5 years, with salvage value of 1,521,527. Annual expenditure would be 1,000,000 for operation and maintenance cost, the company is willing to accept any project that will earn 10% (Minimum Acceptable Rate of Return-MARR) or more between income taxes or all invested capital. Should the project be accepted?

Present Worth Method;

\[-P + (R-D) \left( \frac{P}{A}, i \times \%, N \right) + F \left( \frac{P}{F}, i \times \%, N \right) = 0\]

\[-7607636 + (1,879,209.5 - 1000000) \left( \frac{P}{A}, i \times \%, N \right) + 1521527 \left( \frac{P}{F}, i \times \%, N \right)\]
Trials

\( i^{\%} = 5\% \)

\[-7607636 + 879209.5(4.3295) + 1521527(0.7835) = 2608982.06 \quad \text{i.e.} \neq 0 \]

\( i^{\%} = 25\% \)

\[-7607636 + 879209.5(2.6893) + 1521527(0.3277) = -4744573.5 \]

Interpolation;

\[
\frac{i^{\%} - 5\%}{0 - 2608982.06} = \frac{25\% - 5\%}{-4744573.5 - 2608982.06}
\]

\[
\frac{i^{\%} - 5\%}{-2608982.06} = \frac{20\%}{-7353555.56}
\]

\( i^{\%} = 5\% + 7.09\% \)

\( i^{\%} = 12.09\% \).

Since IRR is greater than MARR (10\%), therefore, the project is viable.

(Edelugo, 2011)
CHAPTER SIX
6.0 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

This work aimed at formulating improved composite flour for increased and sustainable production, thus ensuring food security. The objectives of this research have been achieved. This study involved experimental approach which led to data collection; experiments were conducted at varying mix ratios (Table 3.1), while ingredients were kept constant (Table 3.3).

From the experimental data obtained and the various plots deduced, it is established that; Baking time is a function of composition involved and weight of loaf baked. It was observed that loaves with less percentage composite inclusion baked at lesser time compared to those with higher quantity of composite. Baking temperature affects the product quality of bread from both pure wheat and composite flours. High temperature of above 230°C resulted in tough crumb texture and dark crust colour. While low temperature below 220°C resulted in an unacceptable crust colour and longer baking time. Blend formulation (mix ratios) affects kneading (dough preparation) and proofing. It was observed that in excess of water, and or improper mixing of cassava-soybean flour, dough preparation became almost impossible, as it became sticky to both palms and kneading board. Proofing time is affected by weather and temperature of the day, at warmer temperature, dough proofs faster. Optimal baking temperature ranges from 220 to 230°C, while baking time depends on the weight of dough.

One of the major hindrances to integrating indigenous crops into bread baking is the mode of drying, it is observed that indigenous crops dried using a flash dryer to yield high quality flour is suitable for baking. This study showed the possibility and acceptability of up to 50 percent composite cassava-soybean flour addition to wheat in bread baking, thereby, lowering cost for consumers and increasing profit for commercial bakers. Good and acceptable bread loaves were baked as indicated and through sensory evaluation conducted they were found suitable. Increase in substitution level is synonymous with decrease in acceptability. At 50 percent cassava-soybean substitution, there was 63.22% acceptance, though it is above average. The volumes of bread loaves made from composite flours were lower than those made from pure wheat. In the course of this research, through experiment and consumers’ perception, increased substitution level to 50% non wheat inclusion to bread baking in Nigeria is feasible, linear programming model was used to minimize cost of production. Reducing the cost of bread production serves as a bold step towards ensuring food security and boosting national economy.
in Nigeria. With the feasibility of successful cassava-soy integration into bread baking achieved, there is hope for an affordable cost of living, employment opportunities and increase in food production in Nigeria.

6.2 Recommendations

Based on the experiences gathered during the experiments involved in this work, the following are recommended;

i. Continuous studies are required on composite flours from various locally grown roots, tubers and legumes to supplement wheat flour.

ii. Federal government to give a new directive that would increase substitution level, and support mechanized growing of cassava roots to meet the demand of the flour mills to be able to reduce exports of hard currency.

iii. Since using locally sourced flour in baking revolves around the mode of drying, flash dryer and other speed dryers which at the moment are limited in supply should be made available in the country by the government.

iv. The cassava trust fund should be entrusted in the hands of seasoned managers if the expected results must be achieved.

v. Quality is a critical issue as long as cassava integration into wheat is concerned. For this reason, backward integration of the process technologies (Cassava and soybean processing) is being recommended

vi. Finally, it is a matter of knowing the limitations of composite flours and working within them that brings about optimum performance and acceptance.
REFERENCES


Dear Respondent,

REQUEST FOR RESPONSE TO QUESTIONNAIRE

I am a postgraduate student from the Department of Mechanical Engineering, University of Nigeria, Nsukka. I am currently undertaking a research work titled “Optimization of mix ratio, temperature, moisture content and baking time on the product quality of composite cassava soy flour (CCS) bread.”

You have been selected as one of the respondents to supply the required information for this study. I therefore solicit your cooperation to respond objectively to the questions. It is purely for academic work and all information supplied by you will be strictly treated in confidence.

Yours faithfully

Okonkwo, Bartholomew Chidi
II

SENSORY EVALUATION OF BREAD SAMPLE.

PRODUCT NAME: BREAD FROM COMPOSITE CASSAVA SOY FLOUR (CCS)

Instruction: Tick (✓) where applicable.

Today’s date.

A. Participant’s Data:
   Age.

B. What is your average weekly expenditure on baked products?
   □ <#500   □ #1000 -- #2000 □ #Unknown

   □ #500 -- #1000 □ >#2000

C. Occupation;
   □ Public servant □ Civil servant □ Craftsman/Technician
   □ Business/Trader □ Farmer □ Student □

D. Sex;   □ Male □ Female □

E. Have you heard of composite cassava flour?    □ Yes □ No

F. If yes, through which means?   □ TV □ Internet □ Newspaper □
   □ School □ Radio

SECTION I.

Sensory Parameters: Taste, After taste, Aroma, Crust colour, Crumb colour, Mouth feel
Texture, Overall acceptability.

Key: EL= Extremely like (9); VML= Very much like (8); ML= Moderately like (7); SL =
Slightly like (6); NLnD = Neither like nor dislike (5); = SD = Slightly dislike (4); MD =
Moderately dislike (3); VMD = Very much dislike (2); ED = Extremely dislike (1).
### III

#### B. Sensory evaluation of bread sample A.

<table>
<thead>
<tr>
<th>S/N</th>
<th>Sensory Parameters</th>
<th>EL</th>
<th>VML</th>
<th>ML</th>
<th>SL</th>
<th>NLnD</th>
<th>SD</th>
<th>MD</th>
<th>VMD</th>
<th>ED</th>
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<td>3</td>
<td>Aroma</td>
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<tr>
<td>4</td>
<td>Crust colour</td>
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<td>5</td>
<td>Crumb colour</td>
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<td>6</td>
<td>Mouth feel</td>
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<td>7</td>
<td>Texture</td>
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<td>8</td>
<td>Appearance</td>
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<tr>
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#### C. Sensory evaluation of bread sample B.

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<th>S/N</th>
<th>Sensory Parameters</th>
<th>EL</th>
<th>VML</th>
<th>ML</th>
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<th>MD</th>
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<td>Taste</td>
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<tr>
<td>2</td>
<td>After taste</td>
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<td>3</td>
<td>Aroma</td>
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<td>5</td>
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</tr>
<tr>
<td>6</td>
<td>Mouth feel</td>
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<tr>
<td>7</td>
<td>Texture</td>
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