OPTIMIZATION OF NIXTAMAL MAIZE FLOUR FORTIFIED WITH SWEET POTATO AND EGG FOR *MASA* PRODUCTION

BY

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MEng/SIPET/2019/9974

DEPARTMENT OF AGRICULTURAL AND BIORESOURCES ENGINEERING, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA

AUGUST, 2023

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THESIS SUBMITTED TO THE POSTGRADUATE SCHOOL, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGERIA IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF ENGINEERING IN AGRICULTURAL AND BIORESOURCES ENGINEERING (FOOD ENGINEERING)

AUGUST, 2023

DECLARATION

I hereby declare that this Thesis titled: **''Optimization of Nixtamal Maize Flour Fortified with Sweet Potato and Egg for *Masa* Production''** is a collection of my original research work and it has not been presented for any other qualification anywhere. Information from other sources (published or unpublished) has been duly acknowledged.

ASEMA, James Kator ……………………………..

MEng/SIPET/2019/9974 SIGNATURE & DATE

FEDERAL UNIVERSITY OF TECHNOLOGY,

MINNA, NIGERIA.

CERTIFICATION

This Thesis titled**: ‘‘Optimization of Nixtamal Maize Flour Fortified with Sweet Potato and Egg for *Masa* Production’’** by **Asema James Kator** (MEng/SIPET/2019/9974) meets the regulations governing the award of the degree of MEng of the Federal University of Technology, Minna and it is approved for its contribution to scientific knowledge and literary presentation.

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DEDICATION

This work is dedicated to the great monarch of Zion who lightened me up. I also dedicate this accomplishment to Mr Asema Ephraim Chile whose parental dedication is amazing and to Mrs Asema Nancy Terna for her love and support.

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My deepest gratitude and appreciation is foremost to the great one for His mercies upon my life and destiny. God Almighty never left me until now, I have seen the hand of Yahweh because the Holy ghost lightened me up.

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ABSTRACT

The research seeks to optimize nixtamal maize flour fortified with sweet potato and egg flour for instant masa production. Maize flour, sweet potato flour and egg flour was used as the mixture components at varying levels. The maize flour was subjected to nixtamalization process using lime to enhance the nutritional composition of the produced masa. The evaluated properties of the flours before and after formulation showed that the mixture components (maize flour, sweet potatoes flour and egg flour) are compatible blends for the production of masa. Nixtamalization process increased the moisture content (9.68% – 10%), crude fibre (2.1% - 2.8%), fat (4.1% - 9.2%), swelling capacity (7.67% - 14 g/g) but decreased the ash (3.2% - 2.4%), protein (8.6% - 6%) and carbohydrate content (72.32% - 69.6%). The proximate and functional properties showed that linear mixture terms were significant at $p < 0.05$. The model equations of the analysis showed that the mixture components had influence on the moisture content, fibre, ash, fat, protein, carbohydrate, water absorption capacity, oil absorption capacity, swelling capacity and beta-carotene content. The optimum condition for the production of best fortified masa was found to be 71.8% nixtamal maize flour, 14.5% egg flour and 13.72% sweet potatoes flour with a desirability index of 0.582. Also, the evaluated physical properties of fortified masa showed that it was significant. The sensory score of the fortified masa in comparison to maize and rice masa showed that the fortified masa had an overall general acceptability of 8.15. It was concluded that nixtamal maize masa fortified with sweet potatoes and egg as a recipe was accepted by the populace and therefore recommended for masa production.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

Masa is a Spanish word mostly referred to as all kind of dough. It is also known as *waina* which is a cereal-based spontaneously fermented cake popularly consumed in developing countries as snack or adjunct to breakfast porridges (Owusu-Kwarteng and Akabanda, 2014). It is a bread-like product that is round in shape with brown colour and smooth surface made from different types of cereals flour (Nachana'a *et al.*, 2018). It can be eaten with granulated sugar or honey or soup because of its sour taste (Sanni and Adesulu, 2013). *Masa* is a very popular staple food consumed by over 80% of the Northern Nigeria population of about 47 million; it is also consumed in Ghana, Niger, Burkina Faso and Mali (Ayo *et al.,* 2008). *Masa* is mainly produced from common cereal such as maize *(Zee mays),* rice *(Oriza sativa),* sorghum *(sorghum vulgare)* or millet *(Pennisetum typhoideum).* Rosentrater *et al.* (2015) stated that the production of *masa* has been on the rise and is flourishing in the United States of America. *Masa* from maize is used in the production of maize snack foods and tortilla chips which have been a staple in the diet of Mexican and Central American peoples for centuries.

Globally a nutrition transition is occurring as shown by swift and widespread shifts in food consumption patterns and lifestyle of the people and accompanying with this is an increased prevalence of diet-related diseases. Urban dwellers in developing countries are gradually experiencing a shift from the consumption of western type of snacks to indigenous snacks (Samuel *et al.,* 2015). In Nigeria, there exist a variety of indigenous snacks such as *"Aadun",* a maize-based snack, *"Ojojo"* made from water yam, *"Kulikuli"* from groundnuts, and *"Masa",* produced from cereals. The consumption of these snacks dates back several decades in the country's history, especially among the low income populace, thus contributing to the overall dietary nutrient intake (Samuel *et al.,* 2015).

Cereal grains are fruit of cultivated grasses of the monocotyledonous family (Nachanana'a *et al.,* 2018). Maize *(Zea mays)* is an important cereal grain in the world and it has a diverse form of utilization including human food uses, animal feeds formulation and raw materials for industries (Sanni and Adesulu, 2013). The utilization of maize as a staple food can be achieved in many ways depending on the desired product. It can be eaten boiled, roasted or fermented into traditional food products such as *ogi*, *banku*, *kunnu* and *masa*. Maize can also be processed into flour or used as an adjunct in breweries (Oladejo and Adetunji, 2012).

Fortification is the process of foodstuff enrichment with a mineral component or a vitamin of choice (Smigielska and Joanna, 2010). It is the process of adding nutrients or non-nutrient bioactive components to edible products which could include food, food constituents, or supplements. Fortification is simply the practice of deliberately increasing the content of essential micronutrients in a food to improve the nutritional quality of the food supply that will be of health benefit with minimal risk to human health (World Health Organization (WHO), 2000). Conventionally, the steps involved in the production of *masa* include; Clean the raw maize, washed and soaked for duration of 12 hours at 34 ^{o}C. After which one-fourth of the maize is cooked and mixed with the three-fourth portion that is milled into slurry form. The slurry is inoculated with baker's yeast usually at 1.0% and allowed to ferment overnight (14-16 hours at room temperature 38^{o}C). The fairly thick batter is then diluted with 10cm^3 trona solution of 20%. After which salt and sugar will be added to the batter, stirred vigorously and fried to produce *masa* (Ayo *et al.,* 2008).

1.2 Statement of the Research Problem

The increment in prominent cases of micronutrient deficiency has been on the rise as reported by World health organization in 2002 (World Health Organization & Food And Agricultural Organization (WHO/FAO), 2006). The report identified iodine, iron, vitamin A and zinc as some of the most common deficiencies faced by the global populace. These micronutrients are abundantly available in some crops such as sweet potato, carrot among others as well as other food like eggs. *Masa* which is a staple food is usually produced from mono-grains cereals which are deficient in these micronutrients, hence the need for fortification. The increment in number of Nigeria's population has placed a high demand on chemical fortificants that are difficult to access due to cost; this is a major challenge that requires alternative means of fortification using commonly available foods materials. Sweet potato *(Ipomoea batatas)* that is high in vitamins and minerals are wasted annually in an unquantifiable amount due to its perishable nature and underutilization. Eggs are fragile and highly perishable (Joel *et al.*, 2010) which has limited not only its production but also its utilization and storage life. The conversion of fresh eggs to powder form for better utilization and extended storage life has hitherto been limited.

The nutritional content of *masa* is limited because no single cereal diet has the entire nutrients and the steps involved in its production are complicated, time consuming and laborious hence the limitation in the consumption and production of *masa.*

1.3 Aim and Objectives of the Study

The aim of this research is to formulate nixtamal maize flour fortified with sweet potatoes and egg for instant *masa* production to combat micronutrient deficiency.

Objectives

The objectives of the work are to:

1. Evaluate the proximate and functional qualities of flour from nixtamal maize, sweet potatoes and eggs.
2. Formulate and characterize composite flour blend from maize, sweet potatoes and egg flours.
3. Optimize the composite flour mixture for *masa* production.
4. Evaluate the physical and sensory properties as well as acceptability of the fortified maize *masa*.
5. Compare fortified *masa* with conventional *masa*.

1.4 Justification of Study

Food fortification is recognized as one of the most cost effective methods with long term sustainability to improve health intervention for combating micronutrient deficiency (United Nations International Children's Emergency Fund (UNICEF), 2011). The dependence on maize as a cereal staple food in developing countries has necessitated the need for improving the quality and acceptability of cereal-based foods (Malomo and Abiose, 2019). To meet with the rapid population growth in Africa, fortification of maize *masa* flour will be a remedy towards meeting the projected demand for a balanced food.

Sweet potato is a compatible blend to supplement *masa* produced from maize because of the available amount of vitamin A in sweet potato known to prevent malnutrition (Alam *et al.,* 2016). Fortifying maize *masa* with sweet potatoes will be a suitable alternative for chemical fortificant. The utilization of sweet potato flour as a fortificant will help in the reduction of the annual postharvest losses of sweet potato tubers.

The incorporation of eggs into *masa* will help in solving the challenges of fragility, bulkiness and perishability characteristics of egg as well as make *masa* more acceptable by different categories of people. This is because eggs are highly nutritious food and popular, it is the only food of animal origin that is eaten by so many people and served in a variety of ways universally (Surai and Sparks, 2001). As eggs contain no carbohydrates, it does not have glycaemic index and will therefore be useful in a low glycaemic index diet (Edel and Sinead, 2000). The properties of egg such as emulsification, foaming and thickening make it a good and compatible fortificant for the production of *masa* in the proposed research.

Fortification of *masa* made from maize with sweet potatoes and egg blends is a suitable alternative that will supply the required nutrient in food consumed by the deficient population. Processing of maize, sweet potatoes and egg into *masa* flour will not only reduce postharvest losses due to spoilage but will also extend the shelf life of *masa* that can be easily reconstituted for food. It will be an alternative source of flour for other confectionery products such as tortillas with preserved nutritional qualities.

1.5 Scope of Study

This research is limited to the production and characterization of flours from nixtamal maize, sweet potato and eggs for *masa* production. Properties evaluated were the proximate, functional, physical and sensory qualities of nixtamal maize, sweet potatoes and egg flours. The proximate properties include; moisture content, crude fibre, ash content, protein, crude fat, carbohydrate and beta-carotene. The functional properties of the flour include swelling capacity, water absorption capacity and oil absorption capacity. *Masa* produced from the formulated blends was evaluated for taste, colour, mouth feel, appearance and acceptability.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Shelf life of *Masa*

Masa is a Spanish word known as *waina* which implies all kind of dough. Good quality *Masa* is round in shape with brown colour and smooth surfaces. It is a yeast fermented product prepared in Nigeria and other West African countries from the flour of millet, maize or rice (Ayo *et al.*, 2008). It is produced from a number of different varieties of cereal such as; *Masa-Shinkafa, masa* produced from rice, *Masa-Masara, masa* from maize, *Masa-Gero* from millet and *Masa-Dawa* from guinea-corn. *Masa* is a food that is majorly edible by over 80% of Nigeria population of about 47 million (Igwe *et al.*, 2013).

Dough from *masa* is used to make a variety of products like tamales, pozole and tortillas. The *masa* dough can last for a maximum duration of three (3) days if it is kept in a cool and dry place. However, if kept at room temperature its shelf life is reduced to 12 hours (Nivanutrifoodsllp, 2021).

2.2 Egg Flour Production

Egg as used in diet by human is dated back since the history of antiquity. Egg as food is usually eaten by many people in a variety of ways (Surai and Sparks, 2001). Egg may be used as thickener in meals such as puddings, sauces or cream filling. It is also used in leavening of sponge cakes, quick breads and butter cakes. Egg is used in binding of meat fish and egg loaves, garnishing of soups, salads including dessert and main dishes. Powdered egg were used in the pre historic era due to ease of storage and nutritional quality, during the World War II egg flour had practical advantages in supplying military troops, and were used in the United Kingdom for rationing and were known as

"Ersatz eggs". Seventy- five percent (75%) of egg is known to be in liquid form; hence it can be easily made into powdered form. Some of the advantages of powdered egg include;

i. **Extended shelf life:** Powdered eggs benefit from an extended shelf-life of 18 months, and if properly sealed 5 to 10 years if stored in a cool and dry place that last much longer than regular eggs. Egg powder does not need to be refrigerated.
ii. **Ease of storage:** Dried eggs require much less storage space where substantial supplies of fresh egg can be difficult to handle because of its fragility and larger storage space requirement. Egg powder may be transported more easily without damage than whole egg.
iii. **Ease of use:** As a complementary food supplement for infants and young children, the dry powder can simply be added and mixed with the porridge. Powdered eggs can be used without rehydration when baking and can be rehydrated to make dishes such as scrambled eggs and omelettes.
iv. **Economic advantage:** Compared to whole eggs, egg powder is more affordable.

The following steps can be used to process whole egg into flour as shown in figure 2.1;

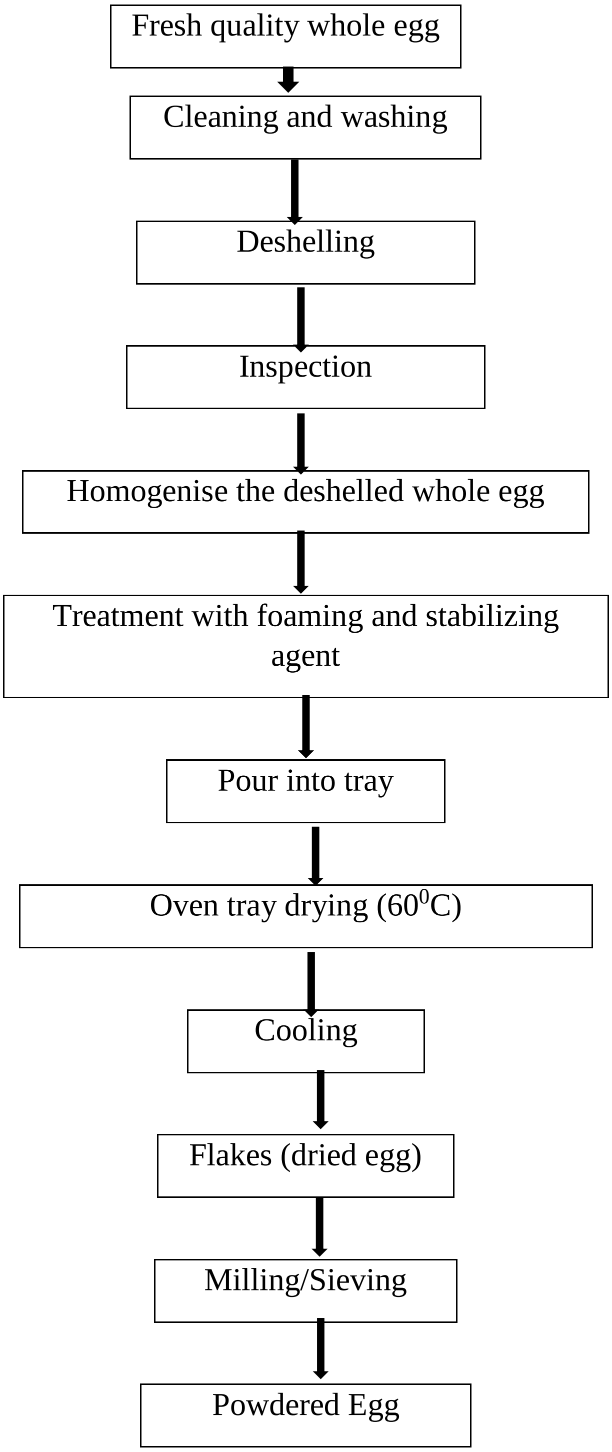

Figure 2.1: Flow chart for the production of egg flour
Source: (Joel *et al.*, 2010)

2.3 Common Cereals Used in the Production of *Masa*

One viable strategy for improving public health is appropriate modification of the food supply to give products that deliver substantiated health benefits while retaining consumer appeal. Cereals grains are prime targets in this regard. As dietary staples, relatively small improvements in grain composition especially in starch and fibre have the potential to translate into significant health gains at the population level when it is incorporated into food (Regina *et al.*, 2007)

Some of the commonly used cereals in the production of *masa* include; maize, rice, sorghum and millet. The utilisation of these Cereals within regions as food and other uses is estimated by Food and Agricultural Organization (FAO, 2014) as presented in Table 2.1.

Table 2.1: Utilisation of major cereals within regions as food and other uses

	Africa	Asia	Europe	North America	South America	Oceania
Rice food	93.1	86.6	86.6	93.6	93.3	81.4
Rice feed	3.0	8.2	8.8	0.0	1.9	0.0
Other use	3.8	3.1	2.5	6.4	4.8	18.5
Maize food	65.4	16.2	6.9	16.2	16.6	20.6
Maize feed	33.3	70.9	88.3	62.0	74.9	74.1
Other use	1.3	12.9	4.8	36.1	8.5	5.2
Sorghum food	78.5	72.8	0.0	6.0	0.0	0.0
Sorghum feed	14.3	27.0	99.6	94.0	99.6	100.0
Other uses	7.2	0.3	0.4	0.0	0.4	0.0

Values are expressed as a percentage of total utilisation for the region.

Source: FAO Statistics website, www.fao.org (2005).

2.3.1 Maize

Maize (*zea mays*) is a member of the cereal family, it is the third most important cereal in the world after rice and wheat and ranks fourth after millet and rice in Nigeria (Abegunde *et al.,* 2014). Cereal grains are fruit of cultivated grasses of the monocotyledonous family and are used for production of different classes of foods. The cereal family are potential sources of vitamins, minerals, carbohydrates, fats, oils and proteins in their natural form. Other examples of the cereal family include: oat, rye, rice, sorghum. Breakfast meals like cornflakes, bread, and pastries, brewing of both alcoholic and non-alcoholic drinks can be made from cereal (Abegunde *et al.,* 2014). Maize belong to the cereal family and can be used in *masa* production because it is one of the most flavourful grain and important crop globally that gets widely used in food manufacturing. The average maize grain is 8–17 mm long, its width is 4–6 mm (Collin *et al.,* 2017). The combination of maize with many other indigenous crops has generated highly varied foods and dishes that are still used in modern cuisine like *masa*. It is a cereal with economic significance and in the global production of cereals crops, maize rank first after rice and wheat. In the developing countries of Africa, maize production is estimated to 33.3 million tonnes yield per 1.5 hacter. Nigeria is one among the largest producers of maize with 4.7 million tonnes per 4.1 hacter according to food and agricultural organization statistics. Maize is a significant food source for the populace and represents a vehicle for vitamin and mineral deficiency intervention. Some of the health benefits derived from maize include;

i. It contains valuable B vitamins and other essential minerals such as zinc, magnesium, copper, iron manganese that are vital to human health.

ii. It is also a good source of antioxidants carotenoids, lutein and zeaxanthin which promote eye health.

iii. The insoluble fibre in maize may also help to lower the risk of colon cancer.

iv. Its high fibre content helps aid with digestion.

v. The fibre content present in maize also assists in weight management by increasing post meal feelings of fullness.

Plate I: Maize Grain

2.3.2 Rice

Rice is a staple food that is broadly produced and consumed around the world to more than half of the world's human populace (Adanse *et al.*, 2019). After maize and sugar cane, rice is one of the most produced cereals in the world with Asia, Africa and America ranking the world top producers (Food and Agricultural Organization Statistics (FAOSTAT), 2012). According to Sharif (2009), 645 million tonnes of rice is generated within 114 nations of the world including Nigeria. Botanically, rice is also known as *oryza sativa* and has a production estimate of 741 million tonnes world-wide with a yield of 4.5 tonnes per hectare (FAO, 2014).

Agriculture is the predominant economic sector in sub-Saharan Africa (SSA), with 70% of rural households depending on rice as a source of their livelihood because it supplies 20% of the world's dietary energy. Rice is an economic crop, which is important in household food security, ceremonies, nutritional diversification, income generation and employment (Perez-consesa *et al.*, 2002). Hence, its consumption is increasing faster than that of any other food staple in Africa at about 5.5% per year (2000–2010 average). This increase is driven by urbanization and related changes in eating habits, and population growth (Seck *et al.*, 2012). Rice consumption was approximately 24 million tonnes per year in Sub-Saharan Africa (SSA) in 2012. Demand for milled rice in SSA is expected to increase by 30 million tonnes by 2035, equivalent to an increase of 130% in rice consumption (Seck *et al.*, 2012). In developing countries like Africa, production of food is grossly inadequate and if something is not done to abate the situation, hunger and malnutrition will sweep through the population. Rice as a cereal will be an alternative to combat hunger as malnutrition continues to be a major public health problem throughout sub-Saharan Africa and the populace (FAO, 2004). Rice is eaten boiled by humans or can be processed into flour however it is relatively uncommon.

2.3.3 Sorghum

Sorghum is a warm season crop, intolerant of low temperatures but fairly resistant to serious pests and diseases. It is known by a variety of names such as great millet and guinea corn in West Africa, Asia and parts of Middle East (Dayakar *et al.*, 2017). The grain consists of naked caryopsis, made up of a pericarp, endosperm and germ. It is classed into four groups namely *grain sorghum*, *forage sorghum glum*, *grass sorghum* or *Sudan sorghums* and *broomcorn.*

Sorghum known as *jowar* is widely regarded as the *new quinoa* due to its gluten-free whole grain goodness. According to FAOSTAT (2015), Africa alone accounted for 23,350,064 tonnes production of sorghum in an area of 23,142,595 hacters. Hence, Sorghum is the second most important cereal after maize with 22% of total cereal area. It is an ancient grain and member of the cereals family that is experiencing a revival because of people moving away from refined wheat products that are not considered healthy. It contains high nutrient content that is attractive and desirable for good health (Nivanutrifoodsllp, 2021). The following health benefits can be derived from the consumption of sorghum;

i. The high levels of manganese in sorghum help maintain calcium levels as a result of calcium absorption.
ii. It is safe for people with celiac diseases.
iii. It can help manage cholesterol levels.
iv. It protects against the risk of diabetes and insulin resistance.
v. The 3- Deoxyanthoxyanins (3 - DXA) present *jowar* may inhibit cancer tumor growth.

2.3.4 Millet

Millets are one of the cereals beside wheat, rice, and maize. It is a major food source for millions of people, especially those living in hot and humid areas of the world. Millets are excellent sources of carbohydrates, protein, fatty acids, minerals, vitamins, calcium, dietary fibre and polyphenols (Devi *et al.,* 2011). Whole grain millet is nutritious and can be consumed as a whole grain, easily digested, naturally gluten free and is essentially organic. It is grown mostly in marginal areas under agricultural conditions in which major cereals fail to give substantial yields (Adekunle, 2012). The different varieties of millet are Pearl millet *(Pennisetum glaucum)*, which comprises 40% of the world production, Foxtail millet *(Setariaitalica)* (Yang *et al.,* 2012), Proso millet or white millet *(Panicum miliaceum)*, and Finger Millet *(Eleusine coracana).* Pearl millet produces the largest seeds and it is the variety most commonly used for human consumption (Mariac *et al.*, 2006). In 2007, global millet production reached about 32 million tonnes with the top producing countries shown in Figure 2.2:

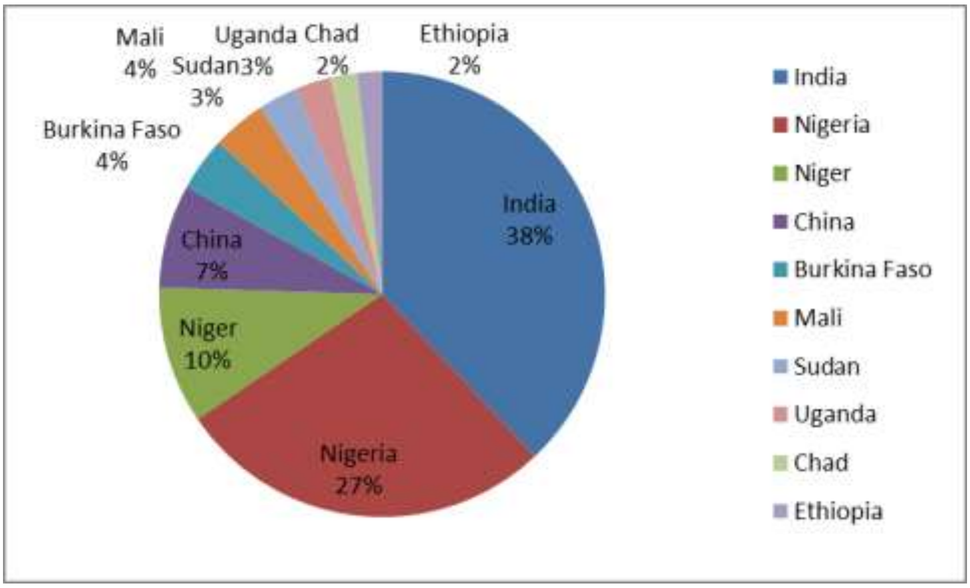

Figure 2.2: Global Millet Production

Source:FAO (2009)

Millet can be used as unique staple food with biodiversity in Agriculture and as food security system to millions of populace across the Sub-Saharan Africa. In Ghana, millet grains serve as the raw material for the processing of various foods such as *koko* (Lei and Jakobsen, 2004), *fura* (Owusu-Kwarteng *et al.*, 2012), and *masa* (Owusu-Kwarteng and Akabanda, 2013). Millets are often ground into flour, rolled into large balls, parboiled, and then consumed as porridge with milk; sometimes millets are prepared as beverages (Issoufou *et al.*, 2013).

2.4 Procedure Used in the Production of Nixtamal *Masa*

The grain of sorted maize is soaked and cooked in lime solution containing calcium oxide (CaO) or calcium hydroxide ($Ca(OH)_2$) or ash and milled to form slurry which is used as the base for different preparations (Danilo, 2003). Nixtamalization of maize grain is a process that was developed by Native American Indians, the kernels of the grain is cooked into the solution of lime water after which it is dehulled and milled to form dough called *masa*. Were traditional products such as tortillas and tamales are derived from the dough (Danilo, 2003). Nixtamalization consist of mixing one third part of whole maize with two thirds parts of the lime solution between 1 to 2 percent of concentration. The cooking duration may vary from 15 to 45 minutes while the cooking temperature been held above 68^{o}C. Furthermore, *masa* dough can be dried and converted into flour by grinding, sieving, classifying and blending it to obtain dried *masa* flour. Dried *masa* flour can be used to make composite flour with other crops as supplements. Also, dry *masa* flour is more shelf- stable which can last for about one year. The merits of nixtamalization include the following;

i. It facilitates pericarp removal and control microbial activities.
ii. It enhances water uptake and increases gelatinization of starch granules
iii. It also improves the nutritional value through an increased availability of Niacin.

Other advantages of nixtamal processing include; It reduces the risk of pellagra, it causes increment in calcium intake especially calcium deficient bone from patients suffering from osteoporosis.

It also contributes to a healthy gut and prevents diseases like cancer through increased resistant starch content, with nixtamalization mycotoxins in kernels is reduced.

2.5 The Essence of Fortification

Food fortification is important because it utilizes staple foods consumed by a large segment of the population without forcing the people to change their original diet. This is technologically feasible and advantageous where fortified food can easily be implemented in developing countries like Nigeria. Food fortification technology has a great significance as fortified food is important in crisis situations; in situations of fragility triggered by economic crises, natural disasters or long term violent conflict. During this period, diet is often inadequate and unbalanced, so food fortified with vitamins or minerals is distributed to prevent malnutrition (Federal Ministry for Economic Cooperation and Development (BMZ), 2012). Fortification is important because it help combat the prominent cases of micronutrient deficiency as recorded by World health organization in 2002. The report identified iodine, iron, vitamin A and zinc as some of the most common deficiencies faced by the world, with food fortification recognized as one of the most cost effective method with a long term sustainability as well as good improved health intervention (United Nations International Children's Emergency Fund (UNICEF), 2011). Fortified foods are better at lowering the risk of micronutrients deficiencies which can inhibit growth and development. Also, fortified foods are advantageous to women of fertile age who need to enter periods of pregnancy and age for lactation with adequate nutrient stores.

Fortifying food with micronutrients is a valid technology because it reduces micronutrient malnutrition which is part of a food-based approach, when existing food supplies and limited access fail to provide adequate levels of the respective nutrients in the diet. Food fortification is a medium that strengthen and gives support to on-going nutrition and should be regarded as part of an integrated approach used on a broader scale to prevent micronutrient malnutrition. This will thereby complement other approaches to improve micronutrient status (WHO/FAO, 2006). Some of the advantages of food fortification include:

i. Fortified foods are also better at lowering the risk of the multiple deficiencies that can result from seasonal deficits in the food supply or a poor quality diet.
ii. Fortification is basically aimed at supplying micronutrients in specific quantity whose summation is equivalent to those provided by a good, well-balanced diet.
iii. Fortification of widely distributed and widely consumed food has the potential to improve the nutritional status of a large proportion of the population, both poor and wealthy.
iv. Food fortification does not require changes in existing food pattern of the people which makes it socially acceptable.
v. Fortification of foods with several micronutrients simultaneously is highly feasible.
vi. It is usually possible to add one or several micronutrients without adding substantially to the total cost of the food product at the point of manufacture.
vii. Fortification is often more cost-effective than other strategies, especially if the technology already exists and if an appropriate food distribution system is in place

2.6 Natural Agricultural Crops used in Place of Chemical Fortificants

Agricultural crops particularly the tuber and root family of the monocotyledonous plant can be used as natural additives as substitutes for chemical fortificants which can be cost effective. Some of the root crops used include;

2.6.1 Sweet potatoes

Sweet potato *(Ipomoea batatas L.)* is one of the most traditional root crops in many countries. It is commonly referred to as yam in some parts of the United States of America with a large, starchy, sweet tasting and tuberous root. It is a versatile, drought resistant, high yielding crop with a short maturity period of three to five months adapting well to wide ecological conditions (Laurie *et al.*, 2012). Sweet potatoes are sweet in nature with a variety of sizes and colours including orange, white, and purple which provide several health benefits (Thuy *et al.,* 2020). It is a root crop that is loaded with nutrient and considered to be one of nature's most perfect vegetables. Among the world's major food crops, sweet potato produces the highest amount of edible energy per hectare per day (Sukhcharn *et al.,* 2008). It consists of about 70% carbohydrates on dry basis of which a major portion is starch, which can be utilized as a functional ingredient in certain food preparations. Sweet potato is an excellent source of vitamin A in the form of β-carotene and also a very good source of vitamin C and manganese. In addition, sweet potatoes are a good source of dietary fibre, natural sugars, protein, niacin, vitamin B5, vitamin B6, vitamin E, potassium, biotin, iron, calcium and copper (Jemiziya and Mahendra, 2017).

Sweet potato can be developed into a variety of products such as dried chips, starch and flour. In Nigeria and other developing countries, sweet potato is one among the most important consumed staple food and has security in promoting root crop in the world, especially in sub-Saharan Africa. Due to its nutritional potentials it can be developed as an alternative into other products for diversification (Odebode *et al.,* 2008). This is because the energy sources derived from sweet potatoes as food is estimated to be 215 Calories per day. The advantages possessed by sweet potatoes compared to other plants are that it can survive in an unfavourable climate, can grow in various types of soil and have economic value that can be calculated. It is a crop that can meet up with and improve the nutritional deficiency of a populace as an alternative food (Liur, 2014). The various forms of sweet potato include; sweet potato products ready to eat, ready to cook and the development of semi-finished sweet potato products for food raw materials such as flour and starch (Juanda and Cahyono, 2000).

Sweet potato is currently ranked as the seventh most important crop in the world with a total production of 103 million tonnes in 2013. It is produced largely in Asia accounting for up to 76.1% of world production in 2013, followed by the African continent 19.5%. According to Food and Agricultural Organization, China, Nigeria, Uganda, Indonesia and the United Republic of Tanzania were the highest producers of sweet potatoes in 2014. In the same year, Nigeria's harvest estimate stood at 3.5 million metric tonnes which was about 3.3% of total world production (FAOSTAT, 2015). According to Abidin (2004), bulkiness and perishability affect postharvest system of sweet potatoes as it has a shelf life of about one week after harvesting, hence, it becomes imperative to process sweet potato into storable products (Ndunguru, 2003). Sweet potatoes can be processed into flour as shown in Figure 2.3.

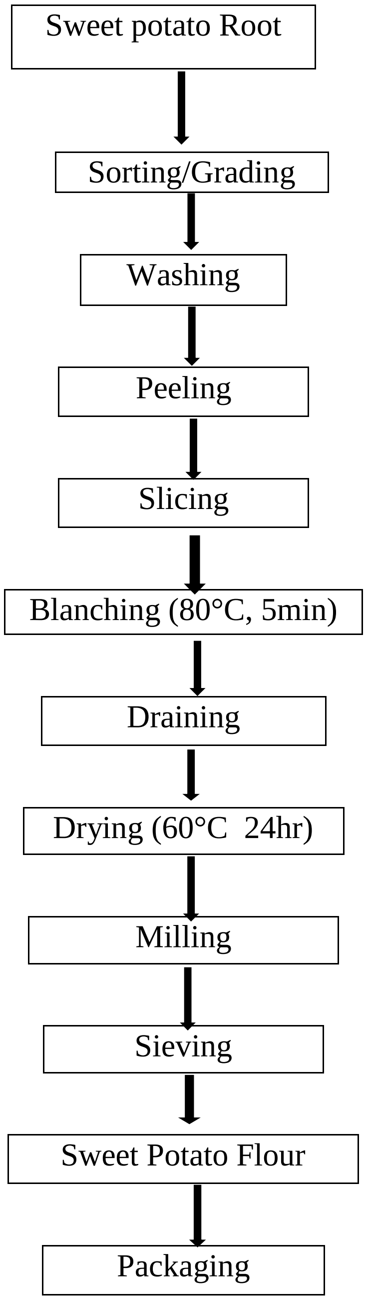

Figure 2.3: Flow chart for the processing of sweet potato into flour

Source: (Endraise *et al.*, 2016)

2.6.2 Irish potato

Potato (*Solanum tuberosum L.*) is an annual, herbaceous, dicotyledonous plant that is cultivated vegetatively. It can also grow as a perennial crop in selected environment or propagated through botanical seeds commonly known as true potato seeds (TPS). Carbohydrate is the primary starch and major component in potato, it makes up 10 – 30 % of the total fresh mass of the tuber (Bertoft and Blennow, 2016) that contributes to its nutritional quality (Singh and Kaur, 2016). Today, potato is grown in one hundred and sixty countries of the world with China, India and Russia being the top producers as well as Africa. It can be eaten fresh or processed into flour for further consumption because processed potato products, especially potato flour, are highly versatile in manufacturing convenience foods into different new products.

Potato is increasingly important to world food security in developing countries because it can supplement and replace grain based diet (Donnelly and Kubow, 2011). It is a major staple food crop because it plays an important role to combat micronutrient deficiency with it relatively high mineral content; it is prevalent in minerals as well as promotes mineral bioavailability such as ascorbic acid (vitamin C) and *beta* carotene. Several B vitamins such as niacin, folic acid, pyridoxine, riboflavin and thiamin are the nutritional component that makes potato a suitable crop to be used for fortification purposes. Potato play a significant role in the health and diet of a population, vitamin A is important in eye health. It also contains diverse number of compounds that are important source of antioxidants. Its protein content is superior to that of cassava and yam flour, slightly lower to that of refined maize meal and similar to that of rice. Processing of potato into flour is the most satisfactory method of creating a product that is not only functionally adequate, but also remain for an extended period without damage. Potato flour can become a highly value added product due to its versatility in function as thickener and colour or flavour improver (Avula *et al.*, 2006).

2.6.3 Carrot

Carrots (*Daucus carata L.*) are biannual crop of the *Apiaceae* (Umbelliferae) family. Carrots originated from Asia, its roots are long and thin, and either purple or yellow in colour. It contains the storage organ known as the edible portion which may be cylindrical, conical, or even spherical in shape. It contains high levels of carbohydrates in the form of sugars and ß-carotene, pre-vitamin A. The antioxidant *alpha* and *beta* carotene give carrots their bright colour – a reason why people consider carotenoids to be the pro-vitamins. Besides, it has some important medicinal values and its plays important role in protecting blindness in children by providing vitamin A. It is consumed fresh or cooked, either alone or with other vegetables, in the preparation of stew, curries and pie. Its fresh grated roots are eaten with salads. Large quantities are also processed either alone or in mixtures with other vegetables by canning, freezing or dehydration. It also helps to increase resistance against blood and eye diseases (Hassan *et al.*, 2005).

Generally, high quality carrots are firm, straight from shoulder to tip, smooth with little residual hairiness, sweet with no bitter or harsh taste, and show no signs of cracking or sprouting (Jairo *et al.*, 2008). Fresh carrots typically have a shelf-life of 3 to 4 weeks at 32 °F and 2 to 3 weeks at 3 to 5 ºC (37 to 41 °F). The average yield of carrot in Nigeria is 15 tonnes per hectare (FAOSTAT, 2012). Realizing the awareness of the people towards the nutrients present in food products, it is important to develop a product which could satisfy the need of such products via food fortification (Mridula *et al.*, 2015). Carrot contains high amount of beta-carotene which is a precursor of vitamin A, it can be used as a good fortificant in the production and utilization of new products with consumer acceptability such as pasta (Mridula *et al.*, 2010).

2.7 Previous Work on Fortified *Masa*

Ayo *et al.*, (2008) investigated the effect of different cereals (rice, maize and millet) on the quality of *masa.* The studies revealed that there were no significant difference in the length, volume and volume index of rice and maize based *masa.* The none significance differences could be due to similarity in the molecular weight and structures of carbohydrates which are the principal functions of volume development during fermentation on the physical quality of *masa.* The effect on the chemical quality of *masa* such as the average protein content of *masa* produced from rice, maize and millet were 8.59, 9.60 and 9.21%, respectively. The relative difference could be due to the chemical composition of the raw cereal. Protein is found in all tissue of cereal grains but the concentration varies from grain to grain. There was a relatively high ash content in the respective *masa* which could be due to the addition of trona and salt added during production. Also, the cereal based *masa* were relatively high in moisture content which could encourage growth of microbes (Okaka, 2005) within short time. However, the relatively high carbohydrate content could make the product of significant source of energy to the consumers. The studies stated conclusively that there was no significant difference in physical, chemical and sensory quality of rice and maize based *masa* but there was slight difference with that of millet. Therefore, maize based *masa* could be made cheaper and affordable to the masses.

Igwe *et al.* (2013) studied the effect of fermentation time and leavening agent on the quality of laboratory produced and market samples of *masa* (a local cereal based puff batter). The functional properties of the flour in study revealed high potential for industrial applications of the flour particularly in the food systems such as *masa* that require thickening and gelling.

Nachana'a *et al.* 2018 studied on microbial quality evaluation of *masa* processed and sold within University of Maiduguri campus. *Masa* was identified as one of the meal mostly consumed by student because it is one of the common ready-to-eat foods. It is also a fast food with low cost compared to other foods. However, higher amount of microbial contaminant of *masa* could emerge as a result of the use of contaminated water and utensils during the production of *masa*.

Méndez-Albores *et al.* (2012) studied on the technological properties of maize tortillas produced by microwave nixtamalization with variable alkalinity. The research was conducted to determine the quality, physicochemical, textural, compositional, nutritional, viscoamylographic and sensory properties of maize tortillas produced with a modified tortilla-making process (MTMP) of variable alkalinity. The evaluated qualities were significant. However, the process of nixtamalization was achieved by the use of microwave oven.

Owusu-Kwarteng and Akabanda, 2014 researched on the effect of soybean fortification of *masa:* a Ghanaian fermented millet-based cake. The study revealed that fortification of commonly consumed cereals with inexpensive plant protein sources such as soybeans can be used to improve the protein quality of staple foods like *masa* through a mutual complementation of their limiting amino acids. The cereal and legume fortification show that soybean fortification accelerates the production of total acids and the growth of lactic acid bacteria during the fermentation of millet dough to produce *masa*. The result obtained was significant in both safety and stability due to the accelerated acid production that enhanced inhibition of pathogens and spoilage microorganisms. The fortification result drew a significant conclusion that protein quality of soy millet blends improved with the addition of soybeans, and *maasa* produced by fortification of millet with 20% soybeans replacement level, prior to milling and fermentation was found to be most acceptable to consumers.

Food and Agricultural Organization (2012) in cereals processing toolkit: Cornmeal *masa* gave a general guideline on the procedures involved in *masa* production as well as the importance of alkaline cooking.

Schaarschmidt and Fauhl-Hassek 2019 carried out a review on mycotoxins during the processes of nixtamalization and tortilla production, this review study showed that nixtamilization is a processing technique that improves the nutritional properties of *masa*. The review also found average reductions of total aflatoxin concentrations in *masa* and tortillas of 94% and 95%, respectively, at 0.6% lime without significant difference compared with the use of 1.87% lime. Schaarschmidt and Fauhl-Hassek 2019 recommended that dry *masa* flour can be produced from low-moisture nixtamal by fine grinding under dry conditions. Hence, with respect to storage, *masa* can be dried and later remoistened for further processing.

Corleone, 2021 contrasted on the nutritional information on *masa* flour verses whole corn in an article on bread and breakfast. The finding of the review article showed that *masa* is a more concentrated source of calories than whole maize and it is a better source of calcium. According to the findings, a cup of serving *masa* flour contains 416 calories while whole maize contains only 132 calories. The reviewed research also stated that *masa* flour is also much higher in carbohydrate and fibre than the whole maize. While a single cup of *masa* contains 87 grams of carbohydrates and 7.3 grams of fibre, whole maize contain 29 grams of carbohydrates and 4.2 grams of fibre.

Jeffery and Maria (2013) researched on processing of maize flour and corn meal food products. The result of their experiment stated that nixtamalised maize when prepared in the house hold or by a small scale processor can be used to make ready to eat finished *masa* products with a limited shelf life. However, on an industrial scale, nixtamalized maize flour may be processed and sold as a shelf stable product that can be prepared for the consumption in the home thereby reducing the meal preparation time and providing convenience.

Nicolas *et al.* 2015 studied on the effect of malting and nixtamalization processes on the physicochemical properties of instant extruded corn flour and tortilla quality. The aim was to prepare instant flour from malted and raw (unmalted) corn flours nixtamalized by the extrusion process and evaluate the effect on the physicochemical properties of tortillas prepared using these flour. The study conclusively stated that the changes during the malting of corn grain and the nixtamalization by the extrusion process improved the water absorption capacity of flours and textural properties of the tortilla and produced a product with acceptable sensory properties.

Benjamin *et al.* (2020) studied the effect of extrusion conditions on the anthocyanin content, functionality and pasting properties of obtained nixtamalized blue corn flour (*zea mays L.*) and process optimization. The research showed that the nixtamalization extrusion process factors affected all parameters evaluated in the extruded nixtamilized corn flour. However, Tortillas obtained from the optimized flour showed suitable textural characteristics in firmness and rollability for consumer acceptance and promising nutraceutical value through high anthocyanin content.

2.8 Statistical Analysis

All data collected was subjected to statistical analysis using design expert software version 13. Design of analysis is simply a body of knowledge and technique that enable the researcher to collect data, analyse and draw statistical inferences from the data in cognizance with the primary objective of investigation. All the parameter mean and analysis of variance (ANOVA) was evaluated to determine model significance on the responses.

2.8.1 Models used for mixture experiment of the fortified blends

The simplest forms of statistical models are the polynomial models where f(x) is a polynomial function with variable (x) and estimable parameters β that is formed only from addition, subtraction, multiplication and non-negative integer exponents. To formulate the mixture components at its optimum point, scheffe's mixture process design was used in this research for the production of quality *masa* flour blend and its acceptability. Formulation is a statistical procedure in which the variation of the ingredients proportion is unity that is ($X_1 + X_2 + X_3 = 100$). These polynomial regression models were used to estimate the functional relationship between the variables.

$$E(y) = \sum_{i=1}^{q} \beta i X i \qquad (2.1)$$

To obtain through replacement of α_o in the ordinary {q, 1} polynomial with $\alpha_o(\sum_{i=1}^{q} Xi)$;

$$E(y) = \alpha_o + \sum_{i=1}^{q} \alpha_o Xi \qquad (2.2)$$

$$= \alpha_o\left(\sum_{i=1}^{q} Xi\right) + \sum_{i=1}^{q} \alpha_i Xi \qquad (2.3)$$

$$= \sum_{i=1}^{q}(\alpha_o + \alpha_i)X_i \tag{2.4}$$

$\sum_{i=1}^{q} \beta_i X_i$ which is known as scheffe's linear model

Hence the quadratic scheffe's model is obtained where in addition each X^2 in the ordinary{q, 2} polynomial

$$E(y) = \alpha_o + \sum_{i=1}^{q} \alpha_o + \sum_{i=1}^{q}\sum_{j\neq i+1}^{q} \alpha_o X_i X_{j+\dots} \tag{2.5}$$

is replaced by

$$X_i^2 = X_i(1 - \sum_{j\neq i} X_i) \tag{2.6}$$

$$= X_i - \sum_{j\neq i} X_i X_j$$

Hence, the quadratic Scheffe's polynomial is given as;

$$E(y) = \sum_{i=1}^{q} \beta_i X_i + \sum_{i\neq j}^{q} \beta_{ij} X_i X_j \tag{2.7}$$

q =The number of components in the mixture

X_i = the i^th^ component

β = Regression coefficients

During statistical analysis, the adequacy of the model is judged by the coefficient of determination (R^2), F-value, adjusted (R^2), predicted (R^2) as well as the model lack-of-fit. Coefficient of determination (R^2) usually measures variation in response variable that is been accounted for by the predictor variable (Nixtamal maize flour, sweet potatoes flour and egg flour). A good model is one that is with a significant value to the response and a non- significant value as the lack of fit. Analysis of variance (ANOVA) is a statistical parameter that help project the influence the factors have by evaluating the F-value. When the F-value is large, it is said to be significant. This implies that the probability is less than 0.05 ($P<0.05$). The backward elimination was used to choose the model that best fit the equation. Statistical analysis on the proximate and functional composition of fortified *masa* is presented in each of the tables.

2.9 Optimization of Fortified Flour Blend

Optimization is the use of specific methods to determine an efficient solution to a problem or design to a process. The goal of optimization is to find the values of the variables in the process that yield the best value of the performance criterion. The three basic component of an optimization problem are; the objective function, process model and constraints. The concept of optimization has vast application and in different field of specialty. It is used in food industries for design and formulation of processes. The proximate and functional properties were optimized to obtain the best condition for *masa* production.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Materials

Maize (*zea mays*), sweet potatoes (*Ipomoea batatas L.*) and fresh egg was purchased at *Kure* market in Niger State and transported to Crop Processing Laboratory, Department of Agricultural and Bioresources Engineering, Federal University of Technology, Minna, Niger State. Other equipments used include; milling machine, measuring cylinder (200 ml), knife, muslin bag, conical flask, soxhlet apparatus, distil water, weighing balance, kheldjal Apparatus, heating mantle, oven, centrifuge, burettes, volumetric flask (250 ml), desiccators and vis spectro photometer.

The reagents used for this research work include; 0.67g/L of lime, n-hexane, tetra-Oxo sulphate (IV) acid, indicator (methyl-orange), acetone.

3.2 Methods

3.2.1 Sample preparation

i. ***Production of nixtamal maize flour***

The sorted maize was cleaned with distilled water and cooked in a solution of 0.67g/L lime at temperature range above 85ºC for 5 - 40 min. The cooked maize was steeped where the remaining maize known as nixtamal separated from some of the pericarp and lime while washing, nixtamal maize was further washed two to three times to remove excess lime. The nixtamal maize was oven dried and milled using milling machine to obtain *masa* flour. The flour was graded using sieve were larger portions of the *masa* was remilled to have a fine particle of the flour. The flour was packaged for further analysis, the proximate and functional qualities were determined using standard methods (AOAC, 2005). Packaged samples of nixtamal maize flour are as shown in Plate II.

Plate II: Nixtamal maize flour

ii. Sweet potato flour production

Sweet potato was sorted, washed, peeled and sliced into thin pieces of about 2 mm. The sliced sweet potato was blanched by steaming at 100^{o}C for 3 minutes to prevent browning reactions. The blanched slices were then dried in a hot air oven at 60^{o}C until the moisture content of 12% was attained. Subsequently, the dried sliced sweet potatoes were milled, sieved with (212 µm sieve - US Standard Mesh No. 70) and packaged inside a plastic container for analysis (Thuy *et al.,* 2020). The proximate and functional qualities were determined using standard methods. Samples of processed sweet potato flour are as shown in Plate III.

Plate III: Oven dried sweet potatoes and flour

iii. Egg flour production

Purchased eggs were candled to confirm its freshness and cleaned by dusting, after which it was washed and allowed to dry. The dried eggs were carefully deshelled to collect both the egg white liquid and egg yolk liquid; it was later homogenized with a metal whisk to obtain a uniform solution. A foaming and stabilizing agent was added to the egg and foam-mat dried at 60°C until dried and allowed to cool. The egg flakes was scooped, milled and sieved with a 60 mm mesh and then weighed. The egg flour was packaged for further investigation. The proximate and functional qualities were determined using standard methods. Samples of egg flour are presented in Plate IV.

Plate IV: Fresh and oven dried egg

3.2.2 Proximate analysis

Proximate analysis were conducted according to the method of the Association of Analytical Chemist (AOAC, 2005)

i. Determination of percentage moisture content

This is simply the determination of the amount of moisture that is present in any given material (component mixture). The containers were thoroughly cleaned with distilled water from dirt and impurities, oven dried and weighed. The initial weight of the container was noted as W1. 5 grams of the sample mixture was weighed into the cleaned moisture can as W2 and oven dried at 105°C for 3 hours until its weight was constant after reheating. The heated sample was transferred into the desiccator to cool after which its weight was noted as W3. Hence, percentage moisture content is given as;

$$\%MC\,db = \frac{W2 - W1}{W3 - W2} \tag{3.1}$$

where,

W1 = weight of empty crucible

W2 = weight of sample and crucible before oven drying

W3 = weight of sample and crucible after oven drying

ii. Crude fibre

Crude fibre is the degree of amount of non-digestible fibre and other components presently existing in food. These constituents have minimal nutrition worth nevertheless offer the bulk essential for good peristaltic action in the intestinal tract. It is the loss on ignition of the oven dried remains left over after successive digestion of a sample with Tetra-Oxo sulphate (vi) acid (H_2SO4) and sodium hydroxide (*NaOH*) solution in a particular state which is applied entirely to dry samples such as grains, pet food, flour products and fibrous materials. This is based on the fact that the samples are defatted and the remains left over for analysis.

About 50 grams of the fat extracted sample was placed into a container containing 200ml of Tetra-Oxo sulphate (VI) acid(H_2SO4) and the soxhlet apparatus was set up, the fat free sample was placed into the condenser above the beaker and boil for 30 minutes. After which a filtering cloth was used to filter as well as wash the sample with distilled water until the washing was no longer acidic, the dictation of acidic nature was determined using an indicator. The non-acidic residue sample was collected and weighed to determine its mass. Thus, percentage crude fibre was determined as;

$$\%\, crude\ fibre = \frac{(b-c)}{a} \times 100 \qquad (3.2)$$

where,

a= weight of sample in grams

b= loss of weight after-ashing during the determination in grams

c= loss of weight after ashing during the blank test in grams

iii. Fat content

To determine crude fat, nearly 50grams of the sample was measured (W1) into a clean portion of cotton material. After which it was enfolded firmly into the clean material. The sample was further positioned into the thimble of the Soxhlet setup, solvent precisely n-hexane was used as it was kept at 60˚C. The operation was allowed to stay in this state for duration of 5 hours. This is in order to enhance efficient fat extraction from the sample. Oil obtained was concentrated from the miscella as the defatted sample was removed from the thimble and partly distilled some of the chemical from the mixture in the flask. The container with oil was weighed constantly as a stable mass (W2) was attained. The container was emptied and mass obtained as (W3).

$$\% \, crude \, fat \, content = \frac{weight \, of \, extracted \, fat}{\text{weight of sample}} \times 100 \quad (3.3)$$

$$\% \text{ crude fat content } = \frac{W2 - w3}{w1}$$

iv. Determination of ash content

Ash content was determined according to the standard of Association of analytical chemist (AOAC). The crucibles were cleaned, dried and weighed. 5 grams of the sample was weighed into the dried crucible and oven dried until the moisture was constant in weight. The oven dried samples were transferred into the muffle furnace using a pair of tongs and ashed at 550^{o}C for 4 hours until white ash was obtained. The sample was then removed from the furnace and cooled in a desiccator and weighed thereafter. Hence, percentage ash content was estimated as;

$$Ash = \frac{mass \, of \, ash}{\text{mass of sample}} \quad (3.4)$$

$$\% Ash \, content = \frac{W3 - W1}{W2 - W1} \times 100$$

v. Crude protein

In determining crude protein, the Kjeldahl apparatus was used. About 0.5 grams of all dehydrated sample was measured using the analytical weighing balance and put into the digestion flask. A dose of catalyst usually Selenium was added to all of the flask moisturised using purified water and mixed with 10 ml of Concentrated tetraoxo sulphate (vi) acid (H_2SO4). The mixture was excited to red hot temperature in a fume cupboard for duration of 2 hours to get a clean mixture. The digest was moved measurably into 100 ml volumetric flask where it was diluted using pure water up to the calibration point. An aliquot of the digest (10 ml) was mixed with equivalent quantity of 45% of Sodium hydroxide (NaOH) solution in a semi-micro kjeldahl distillation apparatus. The blend was purified as the distillate was received into 10 ml of 4% boric solution having 3 drops of mixed indicator usually methyl red and bromocressol green. An overall of 50 ml distillate was collected and titrated against 0.02N H_2SO4 solution. A blank test was setup including digestion of every material apart from the sample. The distillation was also performed on the blank. The titre value of the blank was deducted from original sample as the change gotten was used to estimate the crude protein according to Association of analytical chemist (AOAC) standard.

Thus, % nitrogen is estimated as follows;

$$\% \, Nitrogen = \frac{\mathrm{A-B}}{\mathrm{C}} \times 0.014 \times 100$$

where A = Titre value

B = Blank

C = Weight of sample

$$\text{\%Crude protein} = \text{\% Nitrogen x } 6.25 \tag{3.5}$$

vi. Carbohydrate

Total carbohydrate was determined using the method of difference. That is, by subtracting the mean worth of other factors that were analysed from 100.

Hence;

Carbohydrate = 100 – (% Moisture content + % Crude Protein + % fat + % crude fibre + % Ash) (3.6)

3.3 Beta-Carotene

Beta- carotene was determined according to standard. About 1 gram of the sample was measured into a crucible containing 10ml of the prepared solution. The solution mixture was stirred vigorously after which a filter paper was used to collect the solid particles. The filtrates will further be subjected to a spectrophotometer at different lengths of the wave with a blank as control. The experiment will be repeated for a wave length of 663, 644,633 and 425.5 respectively.

Beta- carotene (mg/100ml) = 0.216*A663 – 1.220*A645 – 0.304*A633 + 0.452*A453 (3.7)

3.4 Determination of Functional Properties

i. Water absorption capacity

Water absorption capacity was determined using the method of Adebowale *et al.* (2005). Ten milliliters of distilled water were added to 1.0 g of each sample in beakers. The suspension was stirred using a magnetic stirrer for 5 minutes. The suspension obtained was thereafter centrifuged (Bosch Model No TDL-5, Germany) at 3555 rpm for 30 minutes and the supernatant was measured in a 10 mL graduated cylinder. The density of water was taken as 1.0 g/cm^3. Water absorbed was calculated as the difference between the initial volume of water added to the sample and the volume of the supernatant.

ii. Oil absorption capacity

Oil absorption capacity was determined using the method of Adebowale *et al.* (2005). Ten millilitres of distilled water were added to 1.0 g of each sample in beakers. The suspension was stirred in Lab line magnetic stirrer for 5 minutes. The suspension obtained was thereafter centrifuged (Bosch Model No TDL-5, Germany) at 3555 rpm for 30 minutes and the supernatant was measured in a 10 mL graduated cylinder. Oil absorbed was calculated as the difference between the initial volume of oil added to the sample and the volume of the supernatant.

iii. Swelling capacity

Swelling capacity was determined by the method described by Adepeju *et al.* (2014). Sample (1 g) was weighed into 50 mL centrifuge tube. Distilled water (30 mL) was added and mixed gently. The slurry was heated in water bath (Gallenkomp, HH-S6, England) at 95°C for 30 minutes. During heating, the slurry was stirred gently to prevent clumping of the sample. The tube containing the paste was centrifuged (Bosch Model No TDL-5, Germany) at 3000 x g for 10 minutes and the supernatant was decanted immediately after centrifugation. The tubes were dried at 50°C for 30 minutes, cooled and then weighed (W2). Centrifuge tubes containing sample alone were weighed prior to adding distilled water (W1).

3.5 Experimental Design for Fortified *Masa* Flour Production.

The experimental design used for this work is the D-optimum mixture design. Mixture design is a specialised form of response surface methodology used in the generation and analysis of data. There are different types of designs however for the purpose of this work; mixture design is suitable because it deals with a combination of mixture components at different levels. The mixture components are; Nixtamal maize flour (x_1), sweet potatoes flour (x_2) and egg flour (x_3). All the three components produced response variables including all the proximate and functional responses of the produced *masa* flour. The mixture design gives a total of 16 experimental runs.

3.5.1 Experimental set up for the formulated *masa* flour.

The basic food components used in the production of fortified *masa* flour in this research work include nixtamal maize flour, sweet potato flour and egg flour. All the three components formed 100% of the mixture with maize flour (x_1), sweet potato flour (x_2) and egg flour (x_3). The mixture design for this research is shown in Table 3.1 while Table 3.2 showed the optimal design experiment for the formulated blends of flour. Design-Expert 13 software was used for design, the combined design gives a total of sixteen runs. All the proximate, functional, physical, sensory and selected mineral properties of the flour were evaluated according to standard.

Table 3.1: Mixture component level

Components	**Amount (%)**	
	Lower	**Higher**
Maize Flour (x_1)	40	80
Sweet Potato flour (x_2)	10	50
Egg Flour (x_3)	10	30

Table 3.2: Mixture optimal design experiment for the formulated blends of flour

Run	Maize flour	Sweet potato flour	Egg flour
1	40.0	50.0	10.0
2	47.5	32.5	20.0
3	80.0	10.0	10.0
4	57.5	17.5	25.0
5	60.0	30.0	10.0
6	67.5	17.5	15.0
7	60.0	10.0	30.0
8	47.5	37.5	15.0
9	60.0	10.0	30.0
10	40.0	50.0	10.0
11	40.0	30.0	30.0
12	40.0	30.0	30.0
13	80.0	10.0	10.0
14	60.0	30.0	10.0
15	70.0	10.0	20.0
16	40.0	40.0	20.0

3.6 Production of Fortified *Masa*

The fortified *masa* from the formulated blend was reconstituted (using the optimal condition obtained from numerical optimization with distilled water) to form a batter where baker's yeast was also added as well as salt pitch and sugar. The mixture constituent was stirred thoroughly and fried to obtain *masa*.

The conventional method of producing *masa* was used as control experiment. *Masa* was produced as described by Ayo *et al.* (2008). Raw maize was cleaned, washed, soaked (for 12 hours at 34^{o}C), ¼ of the maize was cooked and mixed with the ¾ portion (milled into powder). The resulting batter was inoculated with baker's yeast (1.0%) and allowed to ferment overnight (14-16 hours at room temperature 38 ^{o}C). The fairly thick batter was then diluted with 10cm^3 kanwa solutions (20%). Salt (pitch) and sugar (6%) was added to the batter, stirred vigorously using a mortar and pestle to incorporate air and fried in a pan with individual cuplike depression in which 12cm^{3}oil was added. The batter was then fried for 4 minutes on one side, then turned with a small spoon and the other side fried (frying time varies from 6 to 8 minutes) to produce *masa*. The produced *masa* served as the control experiment.

3.7 Determination of the Physical Properties of Fortified *Masa*

The effect of fortification on the physical quality of *masa* was determined according to the method described by Ayo *et al*. (2008). The physical properties of the fortified *masa* from nixtamal maize flour, sweet potatoes flour and egg flour were evaluated as well as the rice and maize *masa*. Evaluated properties include; average thickness, length, average loaf volume and loaf volume index. One way analysis of variance (ANOVA) was used for the physical properties of *masa* in order to compare the variations between the different *masa* using statistical package for social sciences (spss) for conventional, fortified and control. Duncan multiple range tests were used to separate the means and test of significance was accepted at ($p \leq 0.05$).

3.8 Sensory Evaluation of Fortified *Masa*

Sensory evaluation is a method of quality evaluation, this technique deals with the perception of the consumers based on senses for acceptability of the produced *masa* from nixtamal maize, sweet potatoes and egg flour. A committee of fifteen (15) panellists made up of both untrained and trained students and staff from Federal University of Technology, Minna was selected to evaluate the sensory characteristics of the produced *masa*. Some of the quality indices of *masa* evaluated include; colour, taste, mouth-feel, appearance and general acceptability. The selected panellists were provided with water to rinse their mouth for every of the taste evaluation to avoid transfer of previous knowledge into the next stage. Hence, the 9-point hedonic scale was used in the evaluation and analysis of the resulting data as represented in Table 3.3 (Igwe *et al.*, 2013).

Table 3.3: 9-point hedonic Scale for sensory evaluation of the produced *masa*

Dislike extre-mely	Dis like very much	Dislike modera tely	Dis like slightl y	Neither like nor dislike	Like sligh-tly	Like modera-tely	Like very much	Like extre mely
1	2	3	4	5	6	7	8	9

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Qualities of Nixtamal Maize Flour, Sweet Potatoes Flour and Egg Flour

The results of the proximate and functional properties of nixtamal maize flour, sweet potatoes flour and egg flour are as represented in Table 4.1.

Table 4.1: Proximate and functional properties of nixtamal maize, sweet potatoes and egg flour

Sample (Flour)	M C %	Fibre %	Fat %	Ash %	Protein %	CHO %	WAC g/cm^3	OAC g/cm^3	SC g/g	B-carotene
Nixtamal Maize	10.00	2.80	9.20	2.40	6.00	69.60	10.00	12.00	14.00	22.00
Sweet potato	3.10	8.46	2.40	3.00	3.90	79.14	16.00	14.00	20.00	23.00
Egg	6.00	0.91	2.00	1.20	12.00	77.89	6.00	10.00	18.00	18.00

Where: MC, CHO, WAC, OAC and SC represent; Moisture content, carbohydrate, water absorption capacity, oil absorption capacity and swelling capacity respectively.

4.1.1 Effect of nixtamalization process on the quality of maize flour

The results showed that the maize (control) used for the nixtamal process had 9.68% moisture content, 2.10% crude fiber, 4.10% fat, 3.20% ash, 8.60% crude protein, 72.32% carbohydrate and beta-carotene of 24g per 100ml. The proximate composition of maize used for this study is similar to earlier reports that showed that maize contains 7 to 13% protein, 1.4 to 6.0% fat, 74 to 80% carbohydrate and 0.81% ash (Shindano, 2007; Nuss and Tanumihardjo, 2010; Adedeji and Tadawus 2019). Maize contains essential nutrients such as carbohydrate and dietary fiber which provide adequate calorie required by the body (Nuss and Tanumihardjo 2010). Nixtamalization process increased the moisture content, crude fiber, fat but decreased the ash, protein and carbohydrate content, this finding are similar to the reports of Sunico *et al*., 2021 on Physicochemical and nutritional properties of nixtamalized quality protein maize flour and its potential as substitute in philippine salt bread.

Increase in moisture content is due to the increase in water uptake upon soaking maize in alkaline solutions (Pappa *et al*., 2010, Campechano *et al*., 2012; Mariscal-Moreno *et al*., 2015).

The moisture content of all the flour samples did not exceed 15% and thus, may be considered as good quality flour (Ozola *et al*., 2012). Lower levels of crude fat in flour can be beneficial in terms of prolonging its shelf life (Olaoye *et al*., 2007). In terms of crude protein, nixtamalization improved the protein content of maize compared to the initial grain which may be attributed to a concentration effect on nitrogen content (Rojas-Molina *et al*., 2008).

The functional properties of maize (control) was 18 g/cm^3 water absorption capacity, 14 g/cm^3 oil absorption capacity and 7.67 mg/g swelling capacity while the functional properties of the nixtamal maize flour was recorded to be 10g/cm^3 water absorption capacity, 12g/cm^3 oil absorption capacity and 14mg/g swelling capacity. Water absorption capacity and oil absorption capacity decreased significantly for nixtamal maize flours while the swelling capacity increased significantly. The reduction in water absorption capacity is similar to the findings of Bolaji *et al*. 2011 on the water absorption capacity of *Ogi* (a fermented maize product) which reduced with increase in soaking time of maize grains. Variation observed in water absorption capacity could be due to differing particle sizes and starch components of the flour. According to Adegunwa *et al*. 2011, water absorption capacity is dependent on factors such as particle size, amylose/amylopectin ratio and molecular structures of component flours.

The increase in swelling capacity of the nixtamal maize flour may be attributed to increased hydration of starch as reported by Chima *et al*. 2015.

4.1.2 Effect of nixtamalization process on the quality of fortified *masa* flour

Nixtamalization as a process had influence on the quality of fortified *masa* based on the result presented in Table 4.1. This is because nixtamilization process increases gelatinization ability of flour that can cause increase in the swelling capacity. Tabulated result of Table 4.2 showed that the swelling capacity of fortified *masa* flour was high with its maximum value at 26mg/100ml. Also, the ash content maximum value was found to be 13% which is a good indicator that the fortified *masa* contains high mineral content. The proximate and functional composition of fortified *masa* flour experimental design with responses is presented in Table 4.2.

4.2 Statistical Analysis and Model Fitting for Fortified *Masa* Flour

Statistical analysis is a tool used in data analysis to determine how fit a model is in the experimentation carried out. During analysis of the obtained fortified *masa* (nixtamal maize flour, sweet potatoes flour and egg flour) data, each response variable generates a model equation that can be used for prediction.

Table 4.2: Proximate and functional composition of fortified *masa* flour

Run	MC	Fibre	Fat	Ash	Protein	CHO	WAC	OAC	SC	B-carotene
1	3.50	0.065	8.21	7.50	2.00	78.73	18	14	24	2.45
2	6.50	0.060	8.10	6.50	2.40	75.55	14	14	12	9.24
3	4.50	0.055	8.10	4.50	2.00	79.95	18	10	18	14.85
4	5.00	0.070	11.55	5.00	1.80	76.58	16	12	18	1.87
5	7.00	0.110	7.91	3.00	2.50	79.48	16	14	18	17.96
6	9.50	0.115	9.32	13.00	1.60	66.47	20	16	22	12.95
7	9.50	0.165	11.39	9.50	3.20	66.25	16	12	22	11.44
8	10.00	0.105	9.03	7.00	1.80	72.07	16	14	15	12.53
9	16.00	0.175	11.64	9.00	3.00	60.19	12	10	14	14.46
10	13.00	0.160	7.91	5.00	1.20	72.73	18	12	26	10.56
11	18.00	0.130	7.25	4.00	1.80	68.82	16	12	18	13.81
12	14.00	0.115	10.71	10.00	3.00	62.17	14	10	25	12.37
13	4.50	0.125	9.39	5.50	2.00	78.48	16	10	14	13.98
14	4.50	0.105	8.19	6.00	1.40	79.81	18	12	12	13.46
15	4.00	0.175	9.78	13.50	3.00	69.54	18	14	20	14.54
16	3.00	0.125	10.14	5.50	2.00	79.23	16	14	18	13.52

Where: MC, CHO, WAC, OAC and SC represent; Moisture content, carbohydrate, water absorption capacity, oil absorption capacity and swelling capacity respectively.

4.2.1 Proximate properties

4.2.1.1 Moisture content

The moisture content data of fortified *masa* was subjected to statistical analysis. Table 4.2 showed that a linear scheffe's model best fit the data. Also, nixtamal maize flour, sweet potato flour and egg flour have a significant influence on the moisture content.

Also, the interaction between the components has no influence on the moisture content. This result is similar to that of Adegunwa *et al.,* 2011 that studied on the effect of fermentation length and varieties on the qualities of corn starch (Ogi) production. The studies showed that the moisture content is significant at $p< 0.05$. This implies that mixture components will have influence on the moisture content variable.

Table 4.3: Analysis of variance (ANOVA) for Moisture content

Source	Sum of Squares	df	Mean Square	F-value	p-value
Model	128.21	2	64.10	3.89	0.0474 Significant
Linear Mixture	128.21	2	64.10	3.89	0.0474
Residual	214.28	13	16.48		
Lack of Fit	136.90	8	17.11	1.11	0.4775 Not significant
Pure Error	77.38	5	15.48		
Cor Total	342.48	15			

Std. Dev.	4.06	**R^2**	0.3743
Mean	8.28	**Adjusted R^2**	0.2781
C.V. %	49.03	**Predicted R^2**	0.0366
		Adeq Precision	5.0904

The Final equation in coded terms for moisture content; That is,

$$y_{mc} = 3.92*X_1 + 7.06*X_2 + 18.66*X_3 \qquad (4.1)$$

where; X_1 = Nixtamal Maize flour

X_2 = Sweet potatoes flour

X_3 = Egg flour

y_{mc} = moisture content

The model equation for moisture content represented can be used for prediction.

The Model F-value of 3.89 in Table 4.3 implies that the model is significant with P-value less than 0.0500. This suggests that only about 4.74% chance of an F-value this large could occur due to noise. The Lack of Fit F-value of 1.11 implies its non-significance relative to the pure error. This means there is non-significance difference between the mean of moisture content of sample and the mean of moisture content not included in the model. This implies that there is a 47.75% chance that a Lack of Fit F-value this large could occur due to noise. Non-significant lack of fit implies that the model is good. Also, the Predicted R^2 of 0.0366 is not as close to the Adjusted R^2 of 0.2781 as one might normally expect. The result of 0.0366 predicted R^2 measures the ability of the model to forecast data that was not used to fit the model. The value of 36.6% showed that the model have a low predictive power, meaning that the region of prediction is not large. Adequate Precision is a statistical parameter used to measure the signal to noise ratio of a given data. Usually, a ratio greater than 4 is desirable. The ratio of 5.090 indicates an adequate signal that can be used to navigate the design space of moisture content. The model of moisture content showed that the coefficient of variation (CV) is high with a value of 49.03% - which is the reason why its prediction ability is low.

Conclusively, the ANOVA result showed that variation in moisture content can only be 37.43% accounted for by the predictor variables (maize flour, sweet potatoes flour and egg flour). Also, the interactive effect of the predictor components does not have influence on the model. As such it is significantly acceptable.

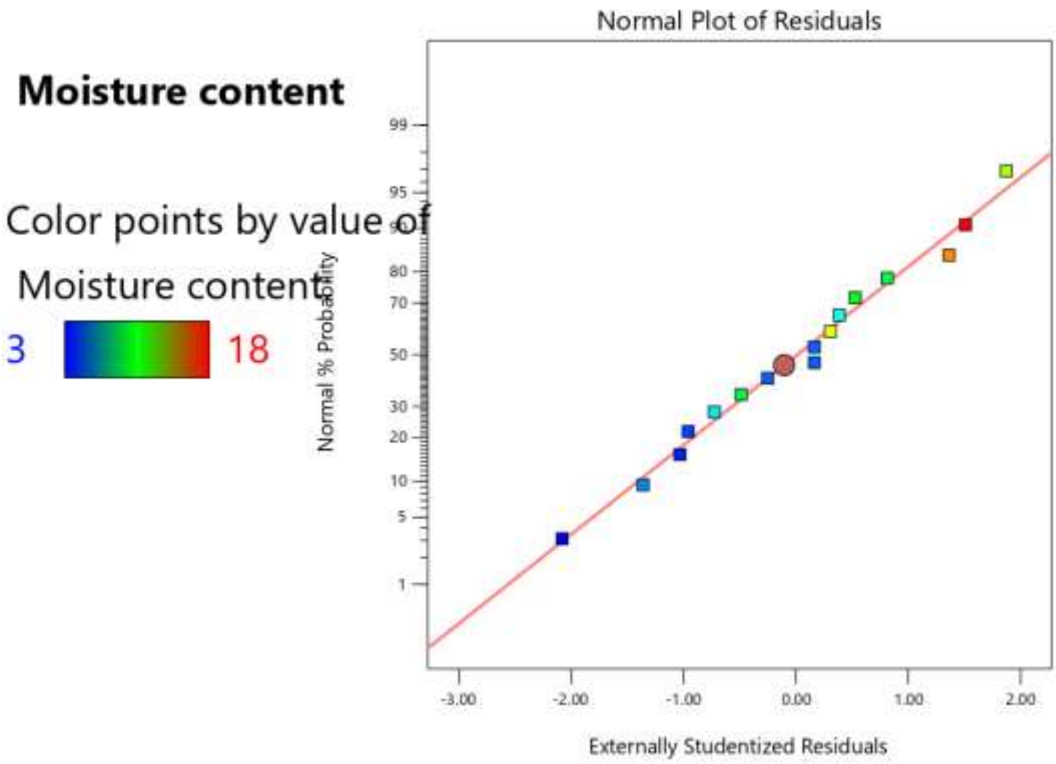

Figure 4.1: Graph of Normal plot against residuals for moisture content

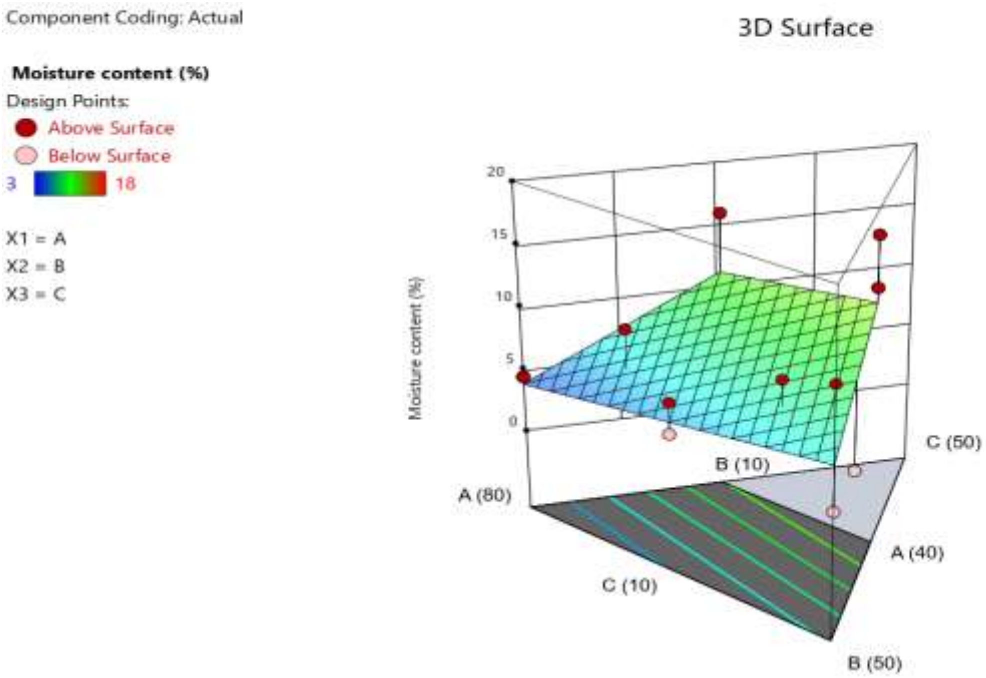

Figure 4.2: Response surface diagram for moisture content

4.2.1.2 Crude fibre

Crude fibre is a measure of quantity of indigestible cellulose and other components present in food. The component usually has little food value but provide the bulk that is needed for proper peristaltic action in the intestinal tract. In Table 4.4 Also, the model linear mixture interaction between maize flour and egg flour (X_1X_3) had influence on the crude fibre at a significant level of $p < 0.05$. The interaction between the three components namely nixtamal maize flour, sweet potato flour and egg flour ($X_1X_2X_3$) had influence on crude fibre at 0.0092. This result is similar to the report of Ayo *et al.,* (2008) on the effect of different cereals on the quality of *masa.* The crude fibre of 0.7% was reported for rice while maize and millet had relatively higher fibre content of 1.2 and 3.0% respectively. The result of this research showed that the linear mixture component of various blends (maize flour, sweet potatoes flour and egg flour) can be used for the production of *masa* with significant effect on crude fibre. The result of the fibre content showed that flours generally are observed to improve baking quality which could be the reason for the common rice base *masa.*

The Model F-value of Table 4.4 with the value 4.31 implies the model is significant. There is only a 2.44% chance that an F-value this large could occur due to noise. The result also showed that the P-values less than 0.0500 indicate model terms are significant. This implies that any values greater than 0.1000 will render the model terms insignificant. The Lack of Fit F-value of 0.24 implies the Lack of Fit is not significant relative to the pure error. There is a 94.61% chance that a Lack of Fit F-value this large could occur due to noise- which is a good characteristic of any model. The analysis of variance is presented in Table 4.4

Table 4.4: Analysis of variance (ANOVA) for Crude fibre

Source	Sum of Squares	Df	Mean Square	F-value	p-value	
Model	0.0144	4	0.0036	4.31	0.0244	Significant
Linear Mixture	0.0035	2	0.0018	2.12	0.1666	
X_1X_3	0.0042	1	0.0042	5.06	0.0459	
$X_1X_2X_3$	0.0083	1	0.0083	9.94	0.0092	
Residual	0.0092	11	0.0008			
Lack of Fit	0.0020	6	0.0003	0.2362	0.9461	Not significant
Pure Error	0.0071	5	0.0014			
Cor Total	0.0235	15				

Std.Dev.	0.0289	**R^2**	0.6104
Mean	0.1159	**Adjusted R^2**	0.4687
C.V. %	24.89	**Predicted R^2**	0.0772
		Adeq Precision	6.7095

Final equation for crude fibre in coded terms

$$\mathbf{Y_{cf}} = 0.0989*X_1 + 0.1199*X_2 + 0.1194*X_3 + 0.2704*X_1X_3 + 2.28*X_1X_2X_3 \quad (4.2)$$

Where; X_1, X_2 and X_3 represent nixtamal maize flour, sweet potatoes flour, egg flour and their various interactions respectively that can be used for model prediction. While y_{cf} represent crude fibre, The Predicted R^2 of 0.0772 is not as close to the Adjusted R^2 of 0.4687 as a result of the difference been more than 0.2. Also, the coefficient of determination (R^2) shows that about 61.04% of variation in crude fibre content can be accounted for by nixtamal maize flour, sweet potatoes flour and egg flour. The model has a good predictive ability of 77.2% - That is, the capacity to predict new data that was not included in the model. Adequate Precision ratio of 6.710 indicates an adequate signal that implies the model can be used to navigate the design space. The low value 0.0289 standard deviation points to the fact that the model points are closer to the regression line.

Conclusively, the low coefficient of variation of crude fibre gives the model a high predictive ability. Also, the interactive effects between the linear mixture components (X_1X_3) and ($X_1X_2X_3$) have a significant influence on the linear model of crude fibre.

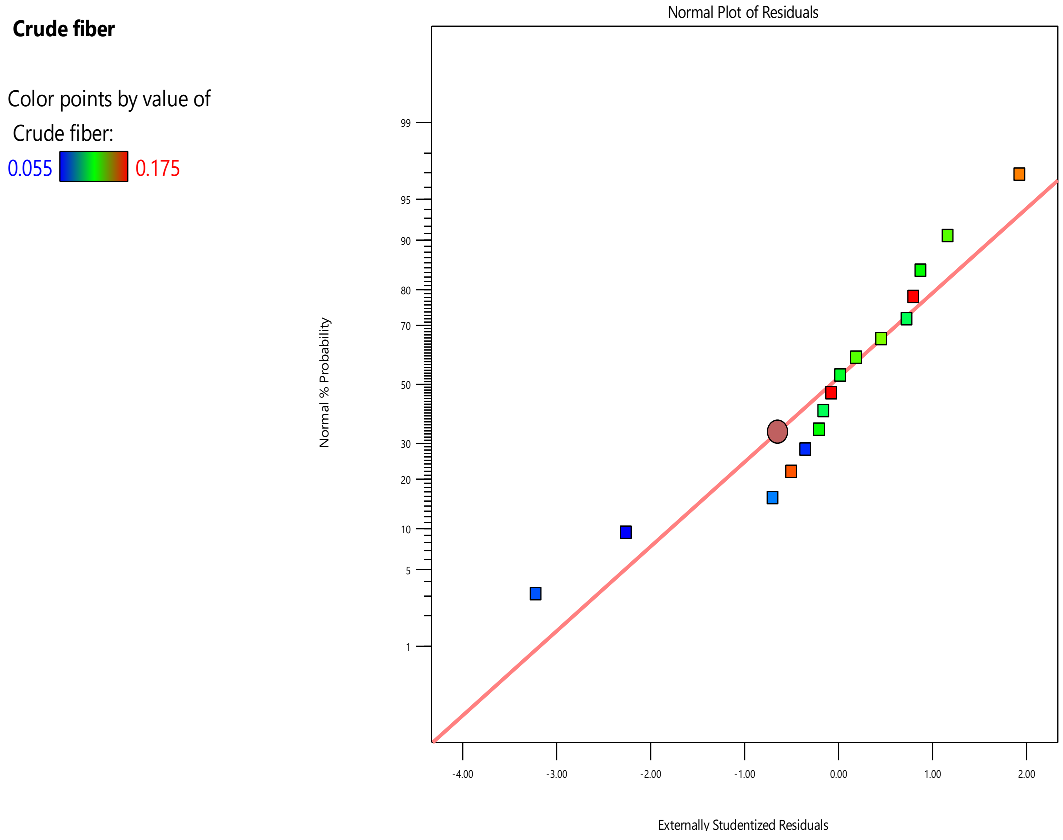

Figure 4.3: Graph of Normal plot against residuals for Crude fibre

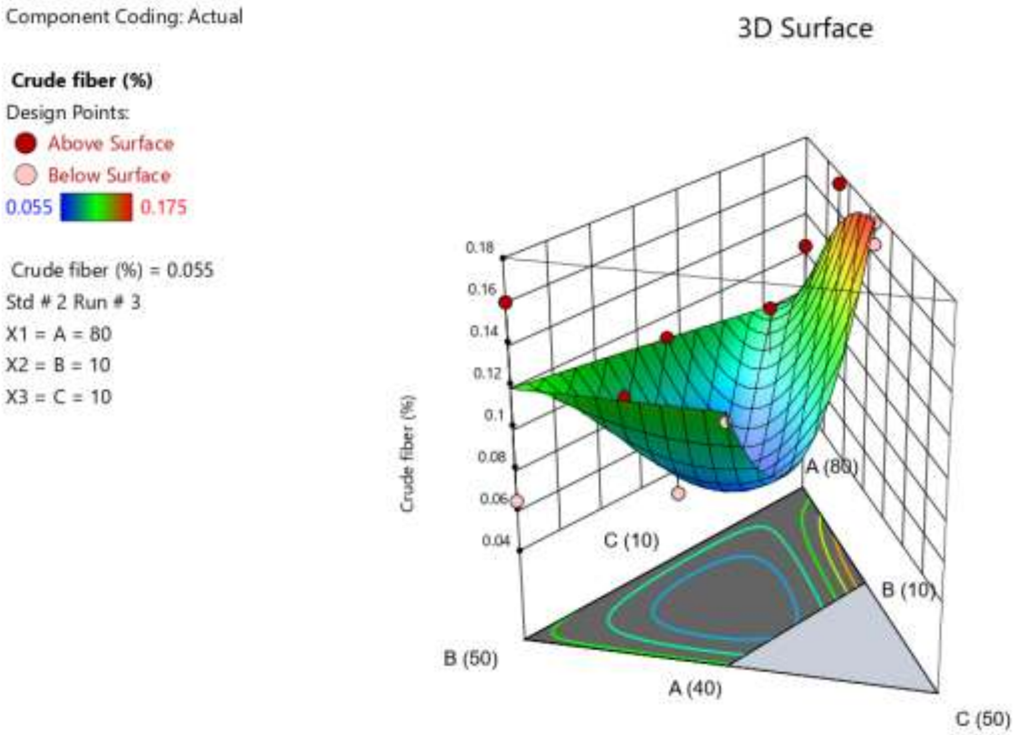

Figure 4.4: Response surface diagram for Crude fibre

4.2.1.3 Fat content

The tabulated result for fat content in Table 4.5 showed a significant interaction with ($p < 0.05$) among the three mixture components (nixtaml maize flour, sweet potatoes flour and egg flour). This implies that both the nixtamal maize flour, sweet potatoes flour and egg flour have influence on the fat content. The fat content is highly low with a mean of 7.33 which is in range with the desired *masa*. The standard deviation of the residuals of 1.03 indicates that the model points are close to the regression line with an average mean value of 9.40 and variability of data points around the mean is 10.96%.

Table 4.5: Analysis of variance (ANOVA) for Fat Content

Source	Sum of Squares	Df	Mean Square	F-value	p-value	
Model	14.65	2	7.33	6.91	0.0090	Significant
Linear Mixture	14.65	2	7.33	6.91	0.0090	
Residual	13.79	13	1.06			
Lack of Fit	7.59	8	0.9485	0.7647	0.6502	Not significant
Pure Error	6.20	5	1.24			
Cor Total	28.44	15				

Std. Dev.	1.03	**R^2**	0.5152
Mean	9.40	**Adjusted R^2**	0.4406
C.V. %	10.96	**Predicted R^2**	0.2330
		AdeqPrecision	7.0910

$$Y_{fc} = 9.33*X_1 + 7.79*X_2 + 12.56*X_3 \quad (4.3)$$

Where y_{fc} represent fat content and X_1, X_2 and X_3 represent nixtamal maize flour, sweet potatoes flour and egg flour respectively.

The Model F-value of 6.91 in Table 4.5 implies the model is significant. There is only a 0.90% chance that an F-value this large could occur due to noise. P-values less than 0.0500 indicate model terms are significant. Values greater than 0.1000 indicate the model terms are not significant. The Lack of Fit F-value of 0.76 implies it is not significant relative to the pure error. Non-significant lack of fit is an indicator that the model is good. Also, only about 51.52% variation in fat content is accounted for by nixtamal maize flour, sweet potatoes flour and egg flour.

The Predicted R^2 of 0.2330 is not as close to the Adjusted R^2 of 0.4406 as one might normally expect because the difference is more than 0.2. This implies the fat content model has only about 23.30% predictive ability of data. Adequate Precision measures the signal to noise ratio. A ratio greater than 4 is usually a good Adequate precision signal. Hence, the signal ratio of 7.091 indicates an adequate signal. The model can be used in the design space for fat content.

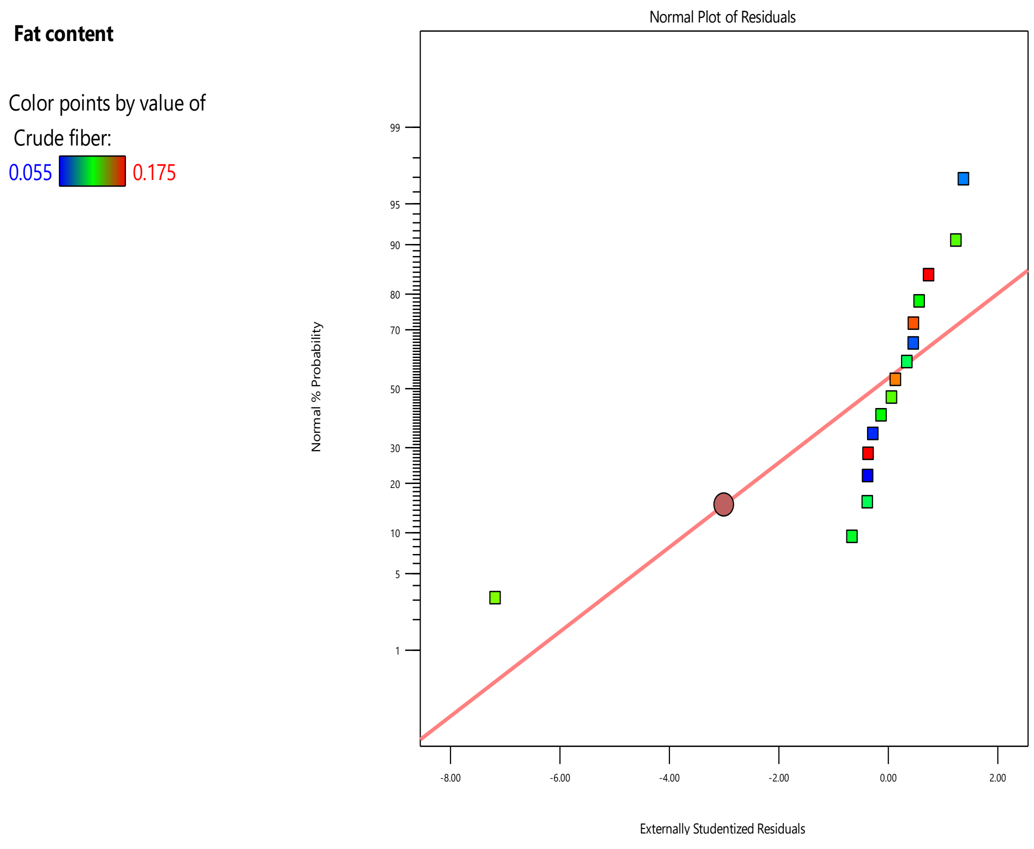

Figure 4.5: Graph of Normal plot against residuals for Fat

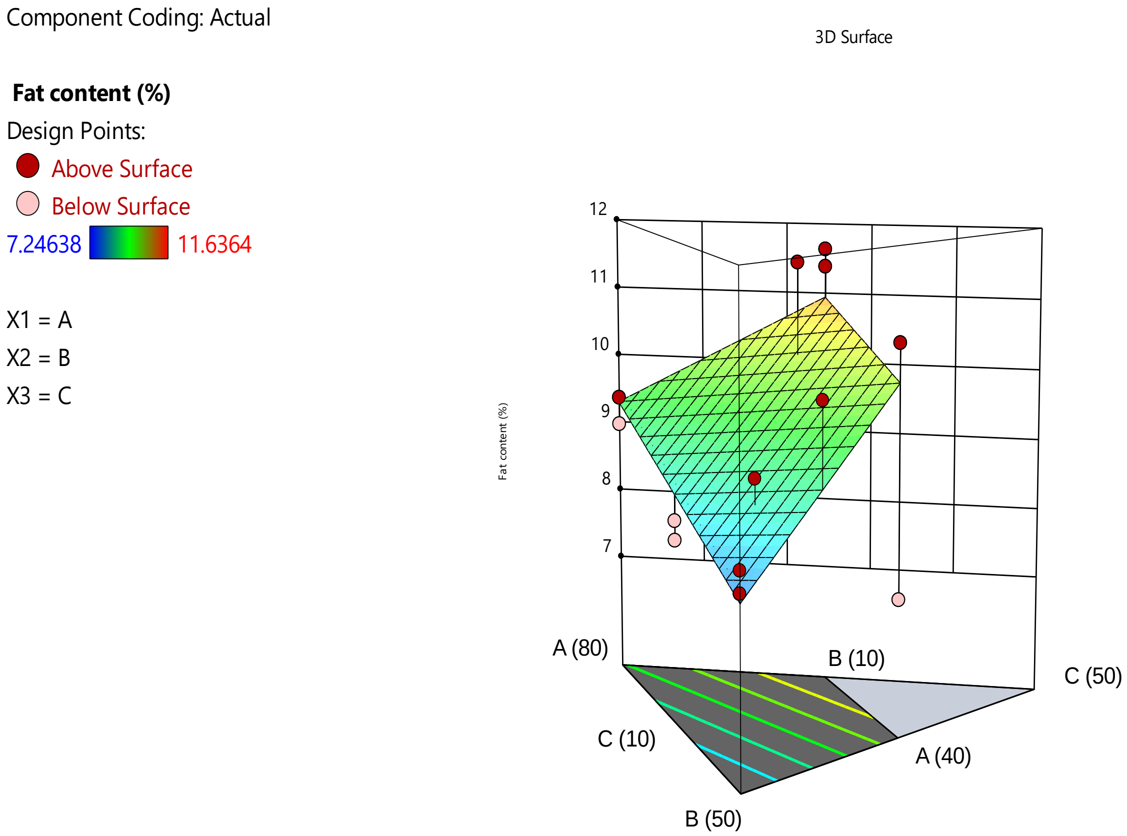

Figure 4.6: Response surface diagram for Fat

4.2.1.4 Ash content

The ash content result obtained is similar to that of Ayo *et al.*, 2008 who studied the effect of different cereals on the quality of *masa*. The ash content of the result is significant but minimal with a mean square of 22.52. This is because the mixture component is already crushed into fine particles that have denatured the cells of the particles.

The Model F-value of 4.74 in Table 4.6 showed that the model is significant. There is only a 1.81% chance that an F-value this large could occur due to noise. P-values less than 0.0500 indicate model terms are significant. The Lack of Fit F-value of 0.83 implies the Lack of Fit is not significant relative to the pure error. There is a 59.47% chance that a Lack of Fit F-value this large could occur due to noise. About 63.27% of variation in ash content is explainable by maize flour, sweet potatoes flour and egg flour.

Table 4.6: Analysis of variance (ANOVA) for Ash content

Source	Sum of Squares	Df	Mean Square	F-value	p-value	
Model	90.08	4	22.52	4.74	0.0181	Significant
Linear Mixture	22.72	2	11.36	2.39	0.1374	
X_1X_3	3.50	1	3.50	0.7358	0.4093	
$X_1X_3(X_1-X_3)$	48.69	1	48.69	10.24	0.0084	
Residual	52.28	11	4.75			
Lack of Fit	26.03	6	4.34	0.8264	0.5947	not significant
Pure Error	26.25	5	5.25			
Cor Total	142.36	15				

Std. Dev.	2.18	**R^2**	0.6327
Mean	7.16	**Adjusted R^2**	0.4992
C.V. %	30.46	**Predicted R^2**	0.0013
		Adeq Precision	7.9663

The final equation in coded terms is given as;

$$\mathbf{y_{ac}} = 4.96*X_1 + 5.90*X_2 + 7.59*X_3 + 8.10*X_1X_3 + 80.35*X_1X_3(X_1-X_3) \quad (4.4)$$

Adequate Precision measures the signal to noise ratio, the ratio of 7.966 indicates an adequate signal that compares the range of predicted values to the average distance between adjacent points. This model can be used to navigate the design space. Also, both the maize flour and egg flour (X_1X_3) have influence on the ash content.

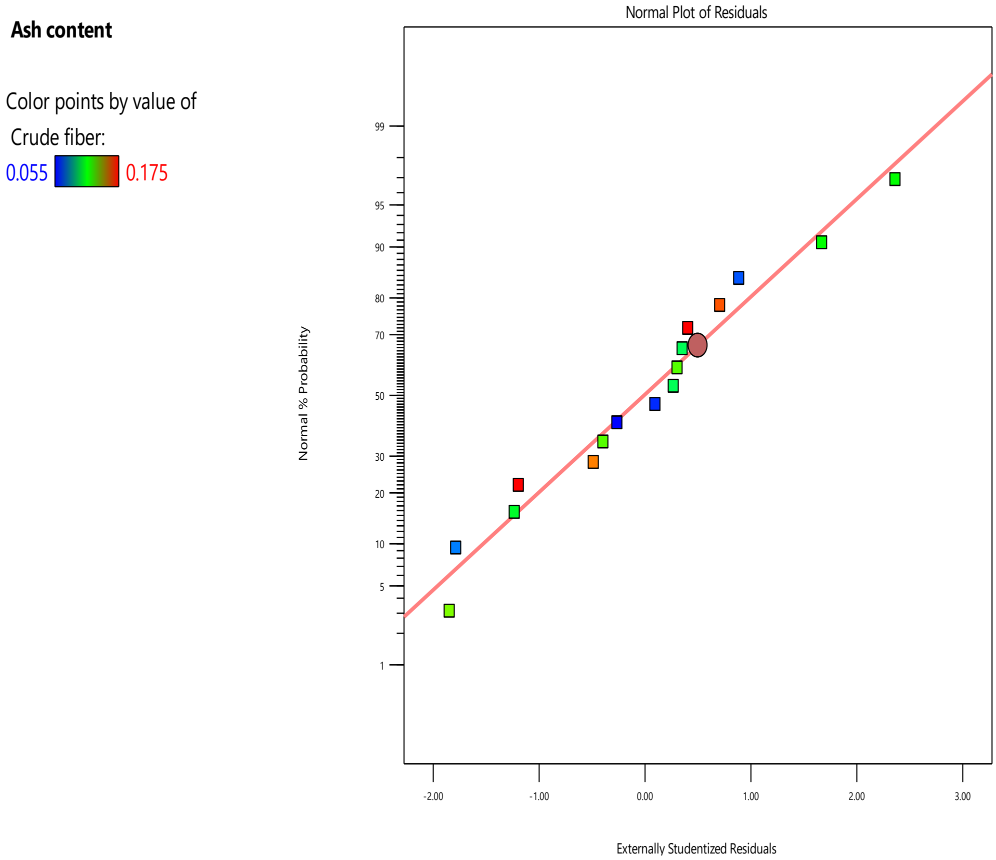

Figure 4.7: Graph of Normal plot against residual for Ash

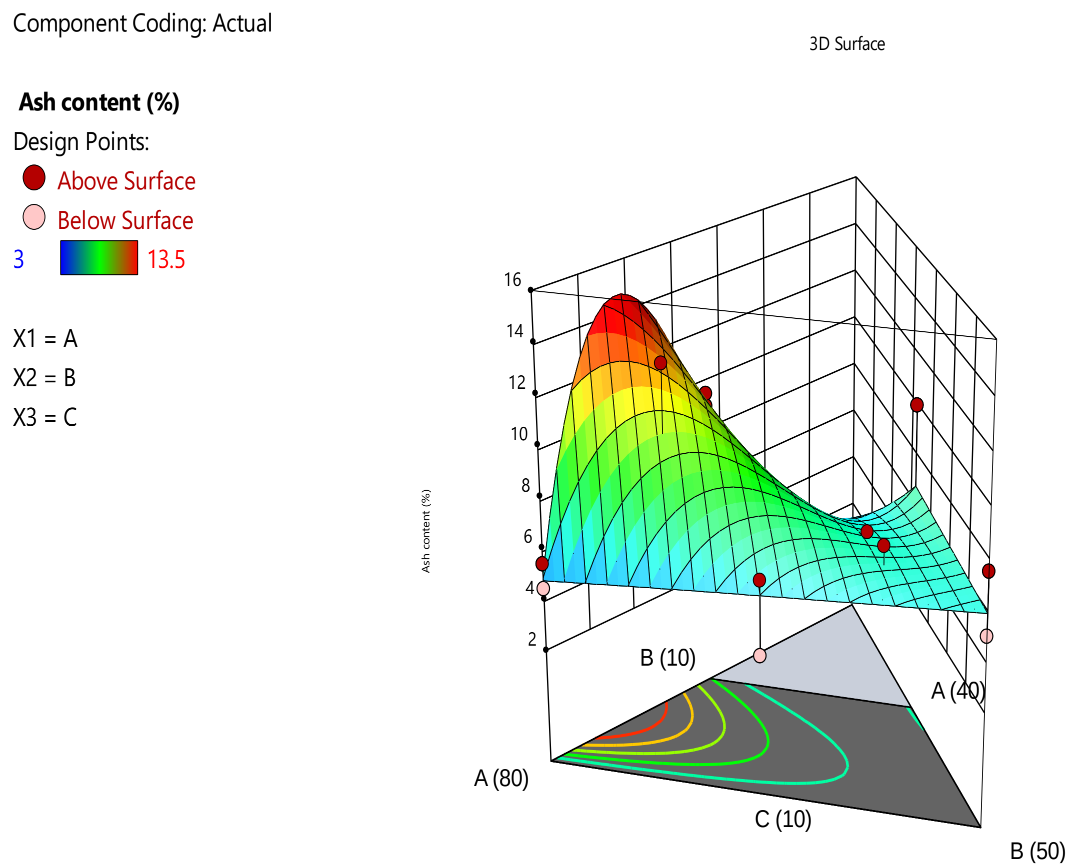

Figure 4.8: Response surface diagram for Ash

4.2.1.5 Crude protein

The result obtained from this research is similar to that of Ayo *et al.*, 2008 that studied on effect of different cereals on the quality of *masa*. The average protein content of *masa* produced from rice, maize and millet were estimated to be 8.59, 9.60 and 9.21%, respectively. Slight differences might be attributed to different mixture components with different chemical composition of the different component mixture. Also, protein is found in food tissues however the concentration is at different rate. However, the obtained result significance in this research is in agreement with the result statement of Ayo *et al.,* (2008) 'The adoption of maize for *masa* production usually increase the protein content to about 1.97% in a given mixture component. The values in Table 4.7

showed that nixtamal maize flour, sweet potato flour and egg flour has a significant influence on the protein content to about 0.0222.

Table 4.7: Analysis of variance (ANOVA) for Crude protein

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	2.52	2	1.26	5.18	0.0222	Significant
(1)Linear Mixture	2.52	2	1.26	5.18	0.0222	
Residual	3.16	13	0.2429			
Lack of Fit	1.49	8	0.1866	0.5603	0.7778	not significant
Pure Error	1.67	5	0.3330			
Cor Total	5.67	15				

Std. Dev.	0.4928	**R^2**	0.4435
Mean	2.17	**Adjusted R^2**	0.3579
C.V. %	22.72	**Predicted R^2**	0.1760
		Adeq Precision	6.0460

$$\mathbf{y_p} = 2.09*X_1 + 1.52*X_2 + 3.54*X_3 \quad (4.6)$$

where;

y_p = Crude protein

The lower value (0.4928) of the standard deviation indicates that the points are closer to the regression line with an average mean of 2.17.

The Model F-value of 5.18 indicates that the model is significant at the value of 0.0222. Meaning P-values less than 0.0500 indicate model terms are significant. Values greater than 0.1000 indicate the model terms are not significant. The model lack of fit p-value of 0.7778 implies it is valid for navigating the design space. The Predicted R^2 of 0.1760 is in reasonable agreement with the Adjusted R^2 of 0.3579. That is, the difference is less than 0.2. The model prediction power is about 17.60 percentage. Also, 44.35 variation in protein content can be accounted for by the three mixture components namely; maize flour, sweet potatoes flour and egg flour. An Adequate Precision measure of 6.046 indicates an adequate signal ratio for protein.

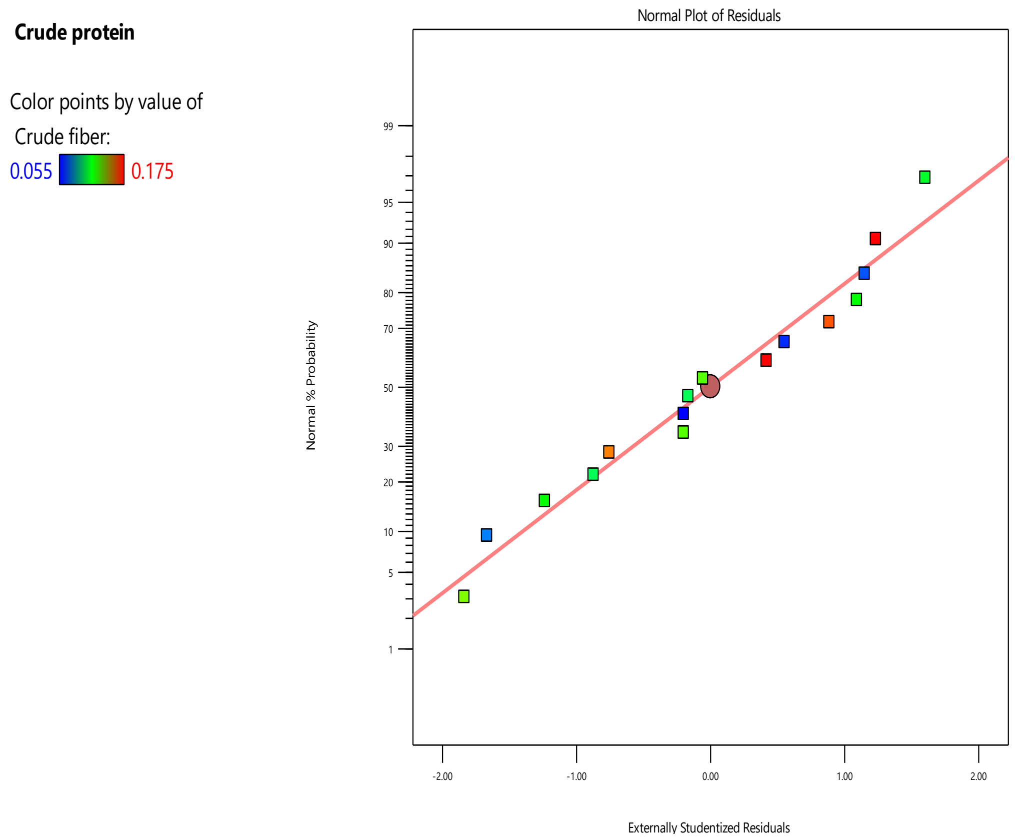

Figure 4.9: Graph of normal plot against residual for crude protein

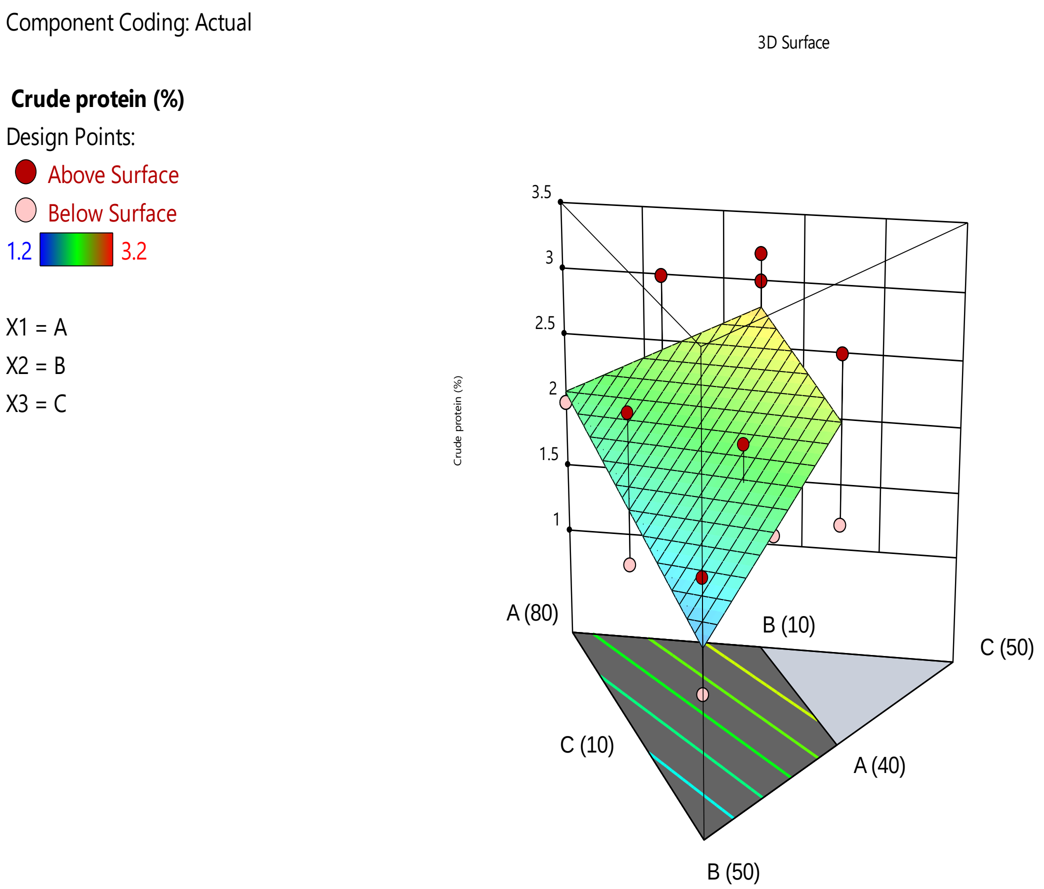

Figure 4.10: Response surface diagram for protein

4.2.1.6 Carbohydrate

Table 4.8 shows the carbohydrate result that is similar to Compaoré *et al*., 2011 who studied on nutritional properties of enriched local complementary flours. The carbohydrate content for the various blends were (65.46±0.06), F2 (70.81±0.01) and F3 (64.51±0.01). Where F1, F2 and F3 represent maize, rice and millet respectively. This research has a high carbohydrate value of about 70.73 mean square – this can be attributed to the combination of the mixture component such as sweet potatoes flour and maize flour which are good sources of carbohydrate. However, this is still within the acceptable region compare to (compaore *et al*., 2011).

Table 4.8: Analysis of variance (ANOVA) for Carbohydrate

Source	Sum of Squares	Df	Mean Square	F-value	p-value	
Model	565.88	8	70.73	5.41	0.0192	Significant
Linear Mixture	357.13	2	178.56	13.65	0.0038	
X_1X_2	6.32	1	6.32	0.4829	0.5095	
X_1X_3	11.53	1	11.53	0.8811	0.3792	
X_2X_3	27.59	1	27.59	2.11	0.1897	
$X_1^2X_2X_3$	105.08	1	105.08	8.03	0.0253	
$X_1X_2^2X_3$	49.06	1	49.06	3.75	0.0940	
$X_1X_2X_3^2$	173.59	1	173.59	13.27	0.0083	
Residual	91.59	7	13.08			
Lack of Fit	31.98	2	15.99	1.34	0.3417	not significant
Pure Error	59.61	5	11.92			
Cor Total	657.47	15				

Std. Dev.	3.62	**R^2**	0.8607
Mean	72.88	**Adjusted R^2**	0.7015
C.V. %	4.96	**Predicted R^2**	0.3820
		Adeq Precision	6.5306

$$\mathbf{y_c} = 78.57*X_1 + 76.39*X_2 + 23.54*X_3 + 8.70*X_1X_2 + 43.54*X_1X_3 + 67.28*X_2X_3 - 1261.92*X_1^2X_2X_3 - 644.83*X_1X_2^2X_3 + 2349.98*X_1X_2X_3^2 \quad (4.7)$$

The Model F-value of 5.41 implies the model is significant. P-values less than 0.0500 indicate model terms are significant. The Lack of Fit F-value of 1.34 implies the Lack of Fit is not significant relative to the pure error. Non-significant lack of fit is good indication of model significance. The Predicted R^2 of 0.3820 simply explains that the model has a 38.20% predictive ability while the Adjusted R^2 of 0.7015 takes into cognizance some included model terms that might not make the model significant. The obtained result showed that there is about 70.2% chance of excluding terms that will make the model insignificant. Adequate Precision measures the signal to noise ratio. A ratio greater than 4 is desirable. The ratio of 6.531 indicates an adequate signal. This model can be used to navigate the design space.

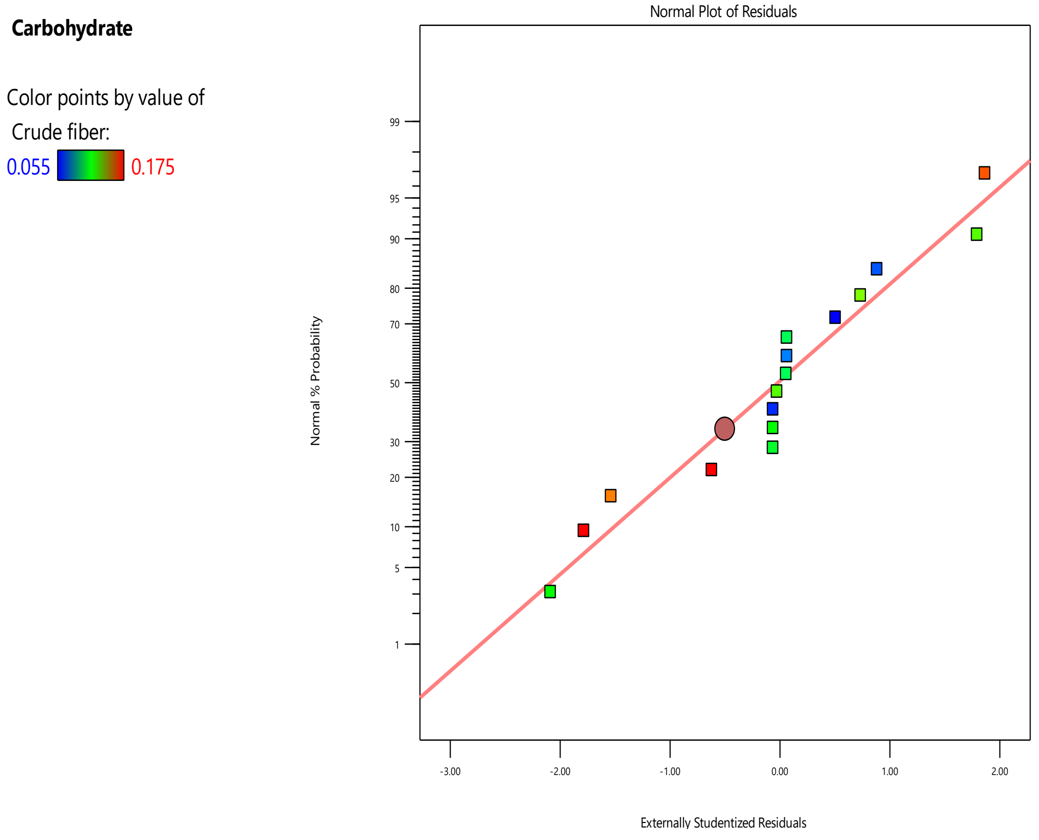

Figure 4.11: Graph of normal plot against residuals for Carbohydrate

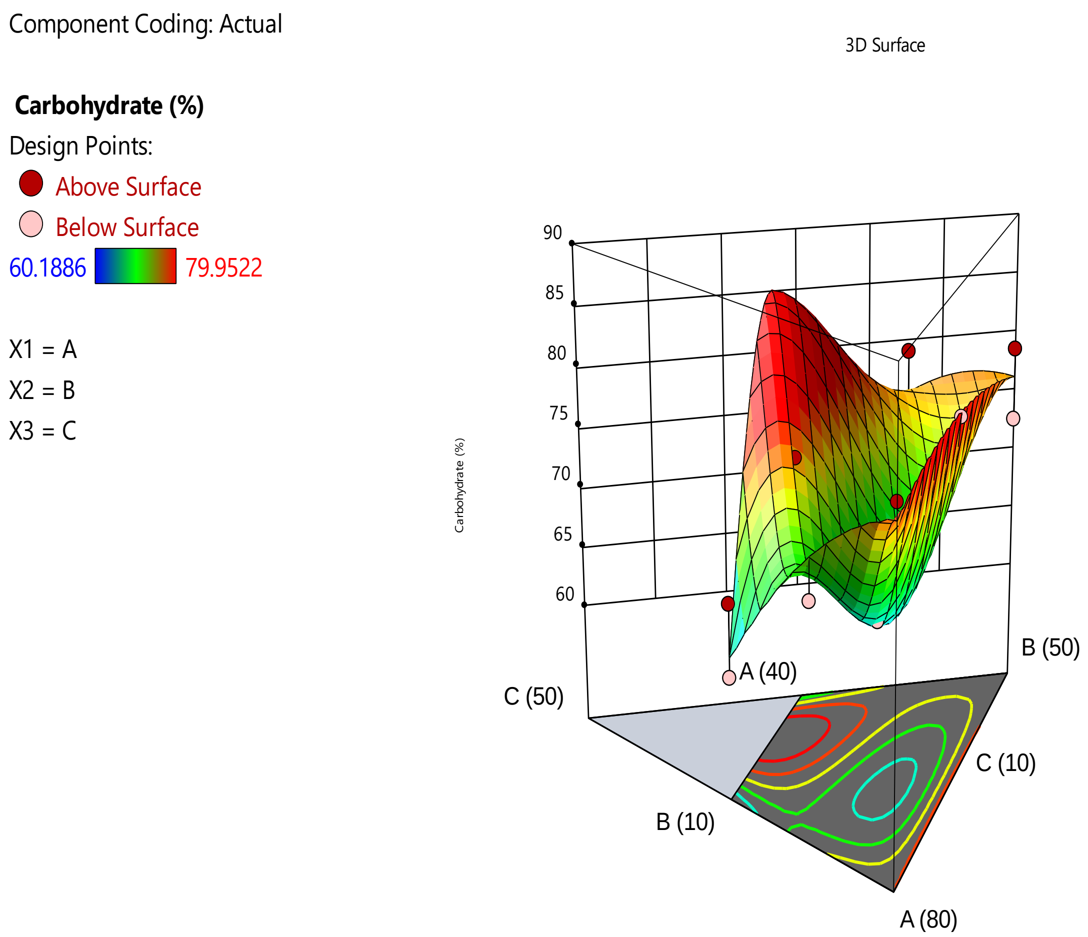

Figure 4.12: Response surface diagram for Carbohydrate

4.2.1.7 Water absorption capacity

This is the amount of water that is needed for gelatinization. All the component mixture (nixtamal maize flour, sweet potatoes flour and egg flour) had influence on water absorption capacity at a significant level of $p \leq 0.05$. The coefficient of determination (R^2) is low – which indicates that only about 38.46 variation in water absorption capacity is explained by the three component mixture (maize flour, sweet potatoes flour and egg flour).

The Model F-value of 4.06 implies the model is significant. P-values less than 0.0500 indicate model terms are significant. Values greater than 0.1000 indicate the model terms are not significant. The Lack of Fit F-value of 0.96 implies the Lack of Fit is not significant relative to the pure error. There is a 54.37% chance that a Lack of Fit F-value this large could occur due to noise. Non-significant lack of fit is a good indication that the model is good.

Table 4.9: Analysis of variance (ANOVA) for Water absorption capacity

Source	Sum of Squares	Df	Mean Square	F-value	p-value	
Model	22.21	2	11.10	4.06	0.0426	Significant
Linear Mixture	22.21	2	11.10	4.06	0.0426	
Residual	35.54	13	2.73			
Lack of Fit	21.54	8	2.69	0.9617	0.5437	not significant
Pure Error	14.00	5	2.80			
Cor Total	57.75	15				

Std. Dev.	1.65	**R^2**	0.3846
Mean	16.38	**Adjusted R^2**	0.2899
C.V. %	10.10	**Predicted R^2**	0.0876
		Adeq Precision	4.5128

Final equation for water absorption capacity in codded term

$$\mathbf{y_{wac}} = 17.82*X_1 + 17.\ 39*X_2 + 11.78*X_3 \quad (4.9)$$

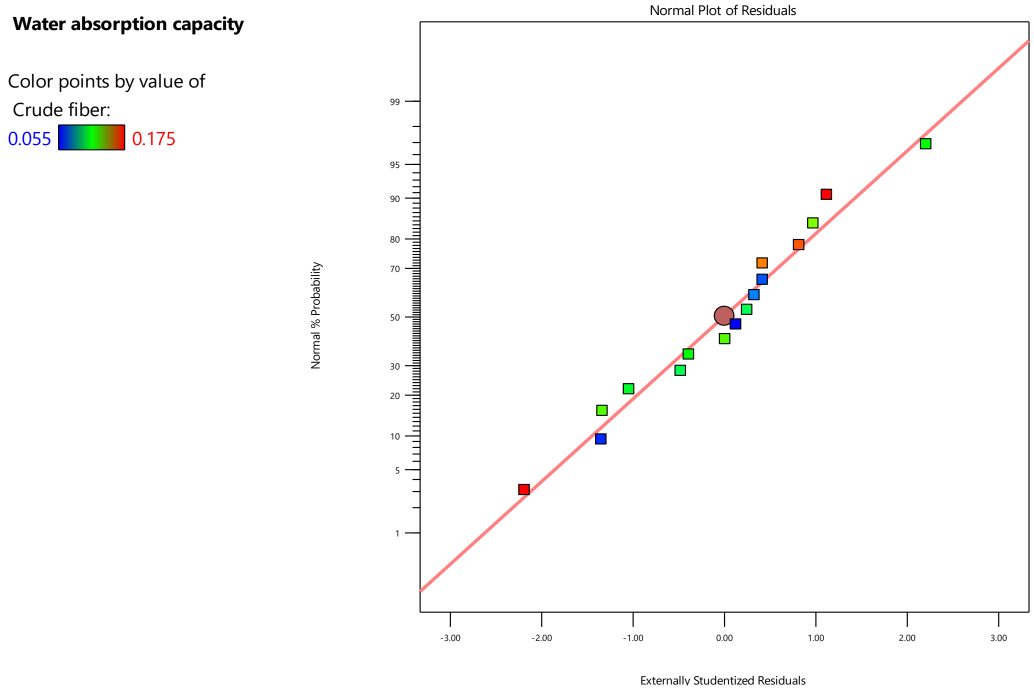

Figure 4.13: Normal plot against residuals for water absorption capacity

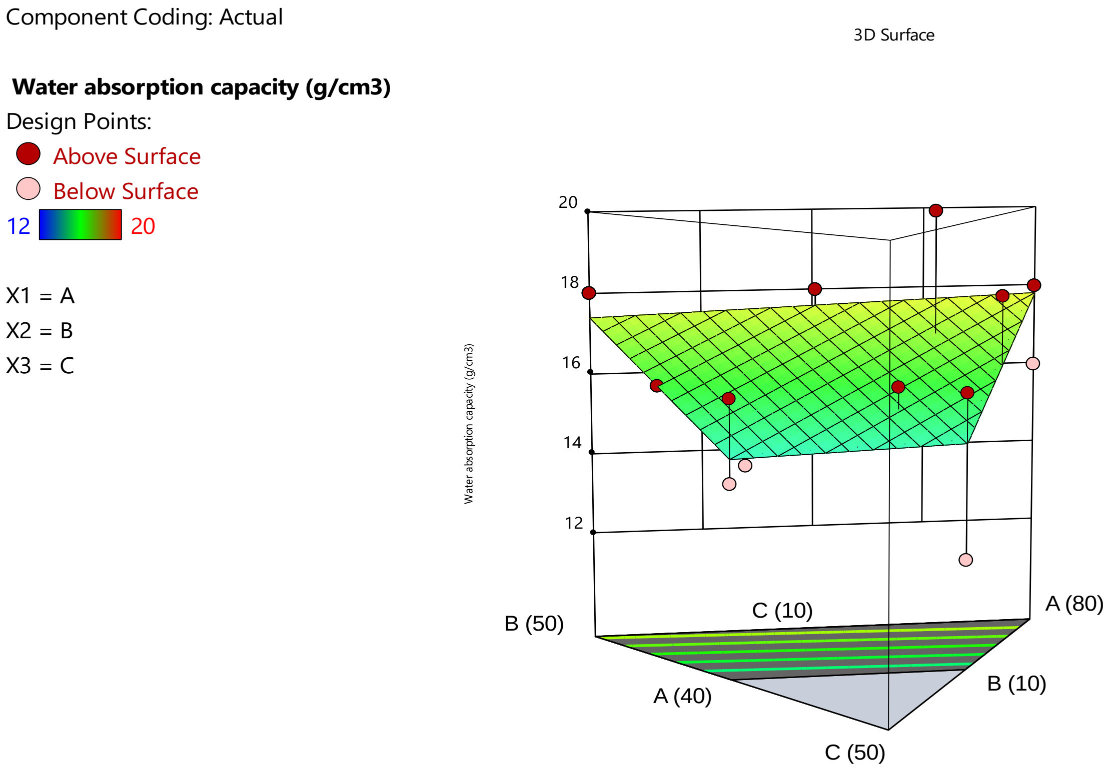

Figure 4.14: Response surface diagram for water absorption capacity

4.2.1.8 Oil absorption capacity

Table 4.10: Analysis of variance (ANOVA) for oil absorption capacity

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	35.14	5	7.03	4.17	0.0262	Significant
Linear Mixture	7.83	2	3.92	2.32	0.1483	
X_1X_2	3.27	1	3.27	1.94	0.1940	
X_1X_3	21.37	1	21.37	12.68	0.0052	
X_2X_3	15.83	1	15.83	9.39	0.0120	
Residual	16.86	10	1.69			
Lack of Fit	8.86	5	1.77	1.11	0.4569	not significant
Pure Error	8.00	5	1.60			
Cor Total	52.00	15				

Std. Dev.	1.30	**R^2**	0.6758
Mean	12.50	**Adjusted R^2**	0.5137
C.V. %	10.39	**Predicted R^2**	0.2155
		Adeq Precision	5.1478

Final equation for oil absorption capacity in codded terms

$$y_{oac} = 10.48*X_1 + 12.84*X_2 – 10.76X_3 + 5.72*X_1X_2 + 44.61*X_1X_3 + 38.27*X_2X_3 \quad (4.10)$$

Oil absorption capacity simply gives a measure of oil absorbed by the flour. It usually facilitates improve the flavour and mouth feel of the flour in baked products. This implies, the higher the oil absorption capacity a flour have, the higher the degree of flavour retention and mouth feel. The coefficient of variation of 10.39% indicates variability of the data points around the mean of 12.50. Also, the interaction between maize flour and egg flour (X_1X_3) and sweet potatoes flour and egg flour (X_2X_3) had influence on the response variable (oil absorption capacity) at $p\leq 0.05$.

The Model F-value of 4.17 implies the model is significant. There is only a 2.62% chance that an F-value this large could occur due to noise. P-values less than 0.0500 indicate model terms are significant. The Lack of Fit F-value of 1.11 implies the Lack of Fit is not significant relative to the pure error. Non-significant lack of fit is good. The Predicted R^2 of 0.2155 is not as close to the Adjusted R^2 of 0.5137. The model can be used to predict new data that was not incorporated into the system by 21.55%. Adequate Precision measures the signal to noise ratio. The ratio of 5.148 indicates an adequate signal. This model can be used to navigate the design space.

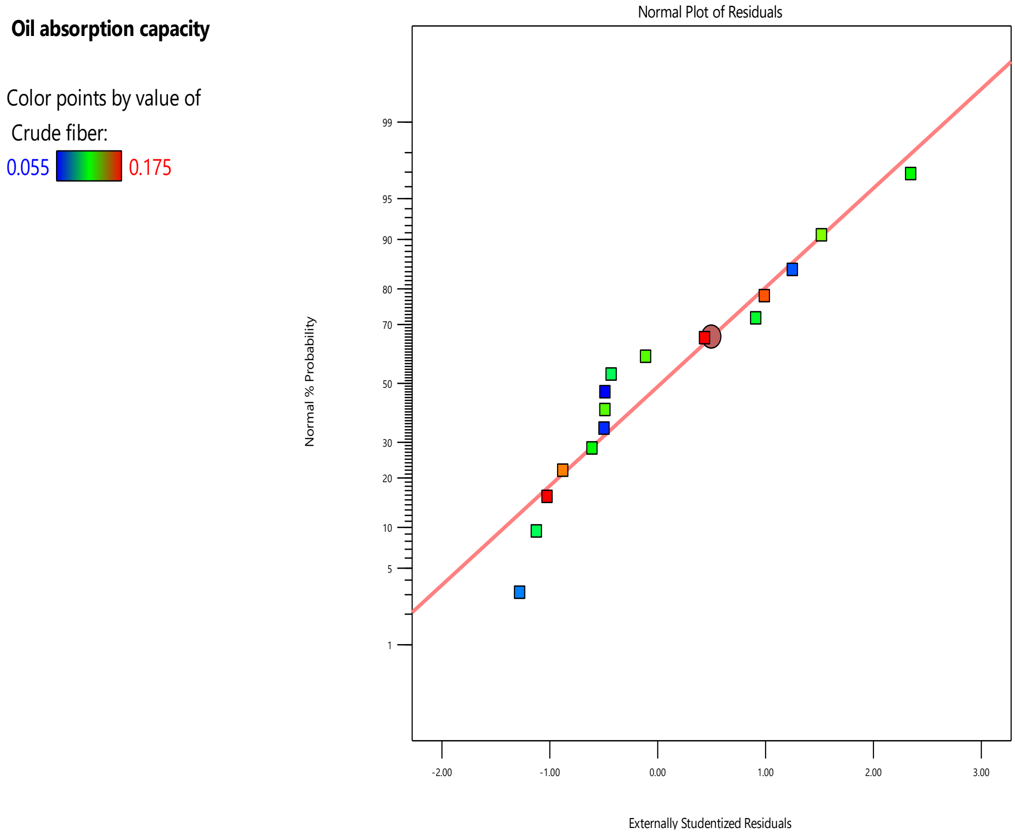

Figure 4.15: Graph of normal plot against residuals for oil absorption capacity

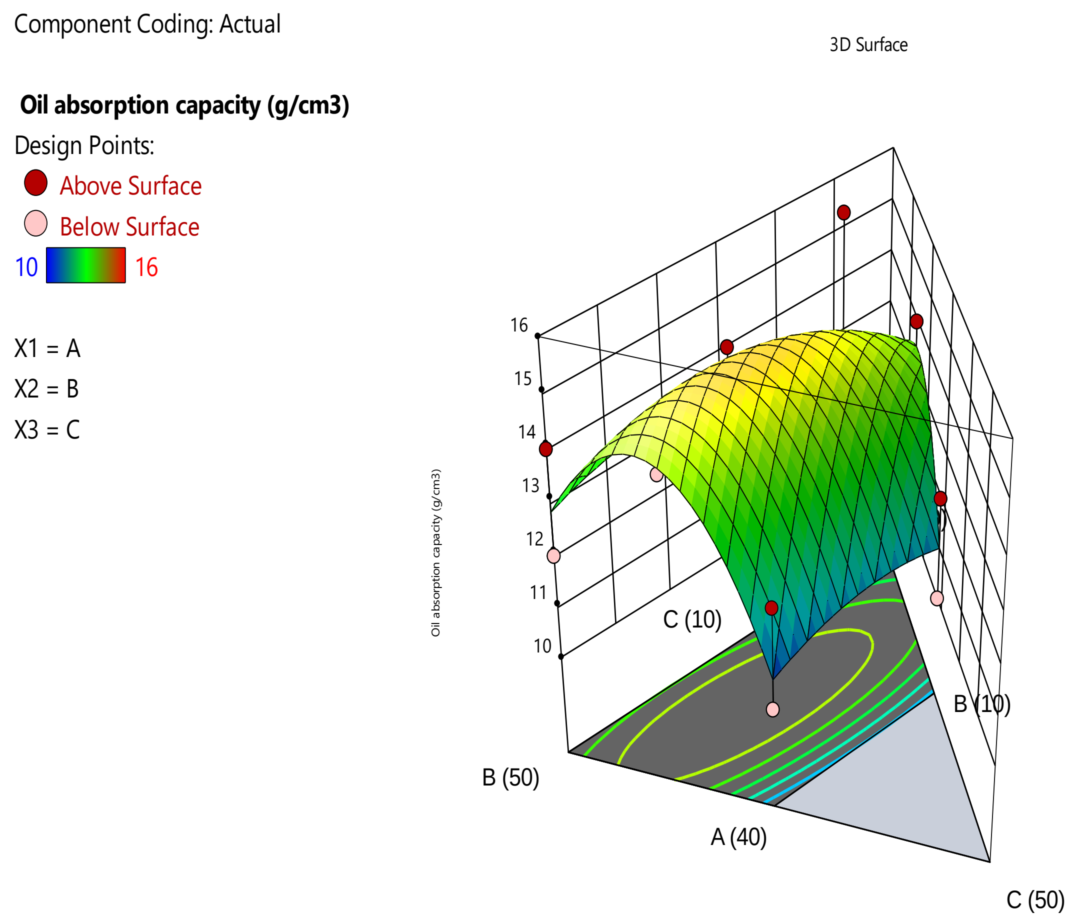

Figure 4.16: Response surface diagram for oil absorption capacity

4.2.1.9 Swelling capacity

The swelling capacity model in Table 4.11 showed that all the basic mixture components; maize flour, sweet potatoes flour and egg flour have influence on the response (swelling capacity). Also, the linear quadratic interaction between maize flour and sweet potatoes flour $X_1X_2(X_1\text{-}X_2)$ is significant at $p \leq 0.05$. However, X_1X_2 is insignificant at $p = 0.0665$. About 55.34% of variation of swelling capacity can be accounted for by maize flour, sweet potatoes flour and egg flour.

Table 4.11: Analysis of variance (ANOVA) for swelling capacity

Source	**Sum of Squares**	**df**	**Mean Square**	**F-value**	**p-value**	
Model	162.70	4	40.68	3.41	0.0480	Significant
Linear Mixture	31.00	2	15.50	1.30	0.3116	
X_1X_2	49.52	1	49.52	4.15	0.0665	
$X_1X_2(X_1-X_2)$	78.13	1	78.13	6.55	0.0266	
Residual	131.30	11	11.94			
Lack of Fit	46.80	6	7.80	0.4615	0.8130	not significant
Pure Error	84.50	5	16.90			
Cor Total	294.00	15				

Std. Dev.	3.45	**R^2**	0.5534
Mean	18.50	**Adjusted R^2**	0.3910
C.V. %	18.67	**Predicted R^2**	0.1246
		Adeq Precision	5.5441

Final equation for swelling capacity in codded terms

$$\mathbf{y_{sc}} = 17.16*X_1 + 23.65*X_2 + 17.97*X_3 - 22.10*X_1X_2 + 92.06*X_1X_2(X_1-X_2) \quad (4.11)$$

The Model F-value of 3.41 implies the model is significant. The Lack of Fit F-value of 0.46 implies the Lack of Fit is not significant relative to the pure error. There is an 81.30% chance that a Lack of Fit F-value this large could occur due to noise. Non-significant lack of fit is a characteristic of a good model. The Predicted R^2 of 0.1246 is not as close to the Adjusted R^2 of 0.3910 as one might normally expect because the difference is more than 0.2- which is still within the desired range. A ratio of 5.544 indicates an adequate signal that the model can be used to navigate the design space.

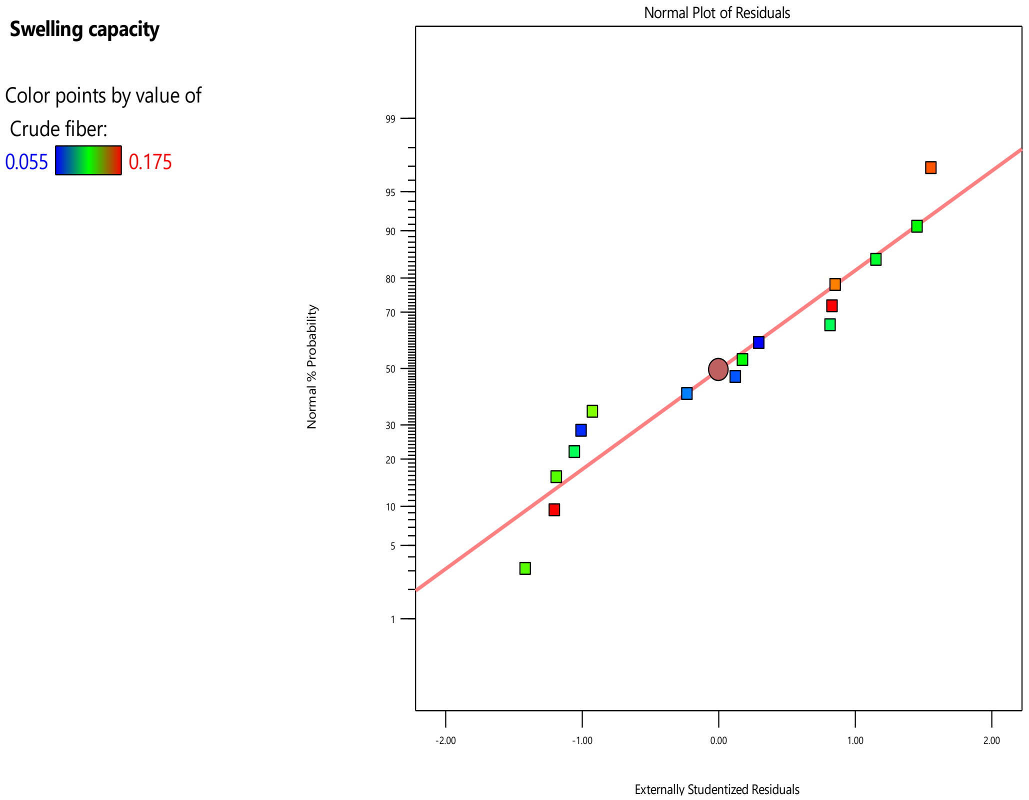

Figure 4.17: Graph of normal plot against residuals for swelling capacity

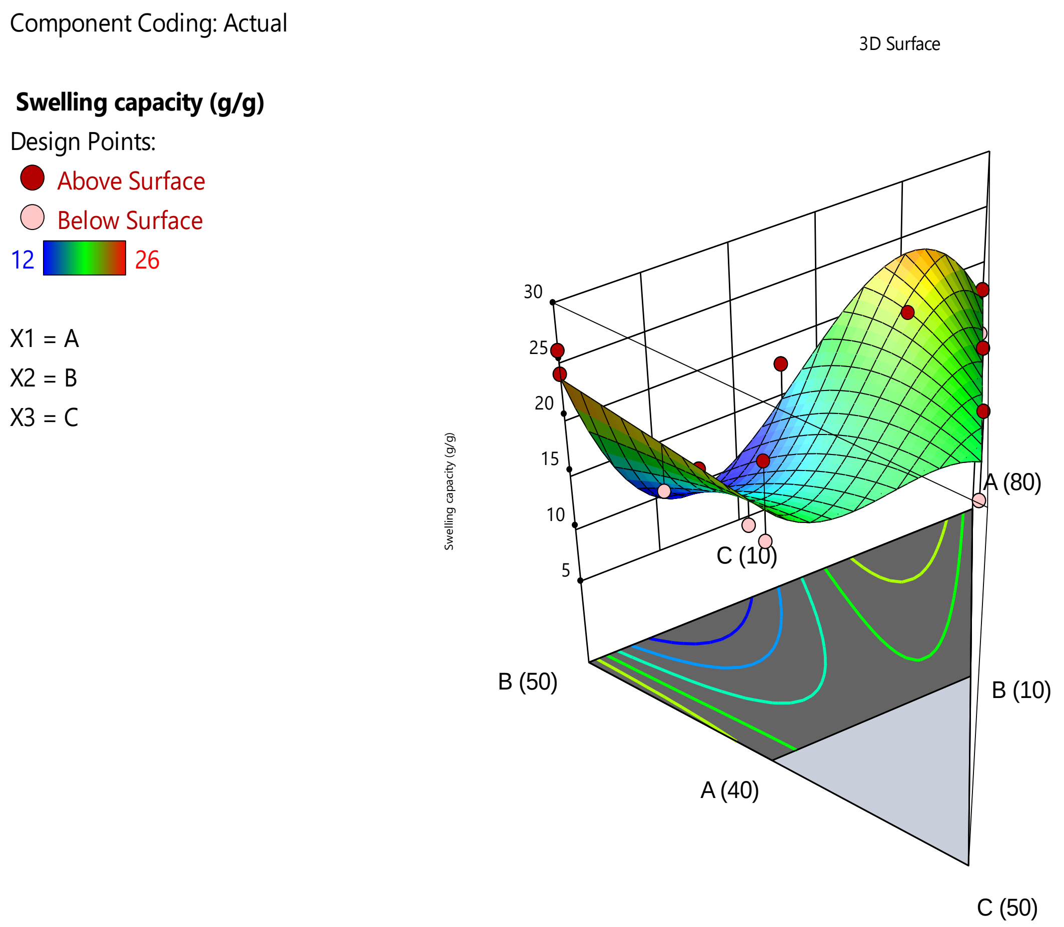

Figure 4.18: Response surface diagram for swelling capacity

4.2.1.10 Beta – carotene

The analysis of variance in Table 4.12 showed the result of beta carotene.

Table 4.12: Analysis of variance (ANOVA) for **beta-carotene**

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	222.48	8	27.81	3.88	0.0453	Significant
Linear Mixture	34.78	2	17.39	2.43	0.1584	
X_1X_2	36.74	1	36.74	5.12	0.0580	
X_1X_3	4.68	1	4.68	0.6529	0.4457	
X_2X_3	12.71	1	12.71	1.77	0.2248	
$X_1^2X_2X_3$	2.41	1	2.41	0.3359	0.5804	
$X_1X_2^2X_3$	1.06	1	1.06	0.1482	0.7117	
$X_1X_2X_3^2$	34.27	1	34.27	4.78	0.0650	
Residual	50.19	7	7.17			
Lack of Fit	1.25	2	0.6270	0.0641	0.9387	not significant
Pure Error	48.93	5	9.79			
Cor Total	272.67	15				

Std. Dev.	2.68	**R^2**	0.8159
Mean	11.88	**Adjusted R^2**	0.6056
C.V. %	22.55	**Predicted R^2**	0.3032
		Adeq Precision	6.8901

Final equation for beta-carotene in coded terms

$$y_{bc} = 14.29*X_1 + 6.63*X_2 - 2.77*X_3 + 20.99*X_1X_2 + 27.74*X_1X_3 + 45.66*X_2X_3\ 191.04*X_1^2X_2X_3* + 94.90*X_1X_2^2X_3 - 1044.13*X_1X_2X_3^2 \quad (4.12)$$

The coefficient of determination (R^2) value of 0.8159 in Table 4.11 indicates that 81.59% variation in beta-carotene can be accounted for by the maize flour, sweet potatoes flour and egg flour. The model interaction terms between maize flour, sweet potatoes flour and egg flour also have influence on beta- carotene with X_1X_3 being significant at $p \leq 0.05$. While (X_1X_2, X_2X_3, $X_1^2X_2X_3$, $X_1X_2^2X_3$ and $X_1X_2X_3^2$ being insignificant) however with a common interaction that had influence on the response. The equation in terms of coded factors can be used to make predictions about the response for given levels of each factor. The Model F-value of 3.88 implies the model is significant. Meaning there is only a 4.53% chance that an F-value this large could occur due to noise. The model P-values less than 0.0500 indicate model terms are significant. The Lack of Fit F-value of 0.06 implies the Lack of Fit is not significant relative to the pure error. There is a 93.87% chance that a Lack of Fit F-value this large could occur due to noise. Non-significant lack of fit is good. The Predicted R^2 of 0.3032 is not as close to the Adjusted R^2 of 0.6056 as one might normally expect; That is, the difference is more than 0.2 which is still within range. Adequate Precision measures the signal to noise ratio. A ratio greater than 4 is desirable. The ratio of 6.890 indicates an adequate signal. This model can be used to navigate the design space. The standard deviation value of 2.68 signifies the data points are closer to the regression line in the model. In summary, the generated model for beta- carotene is significantly acceptable with a high degree of accountability by the component mixtures.

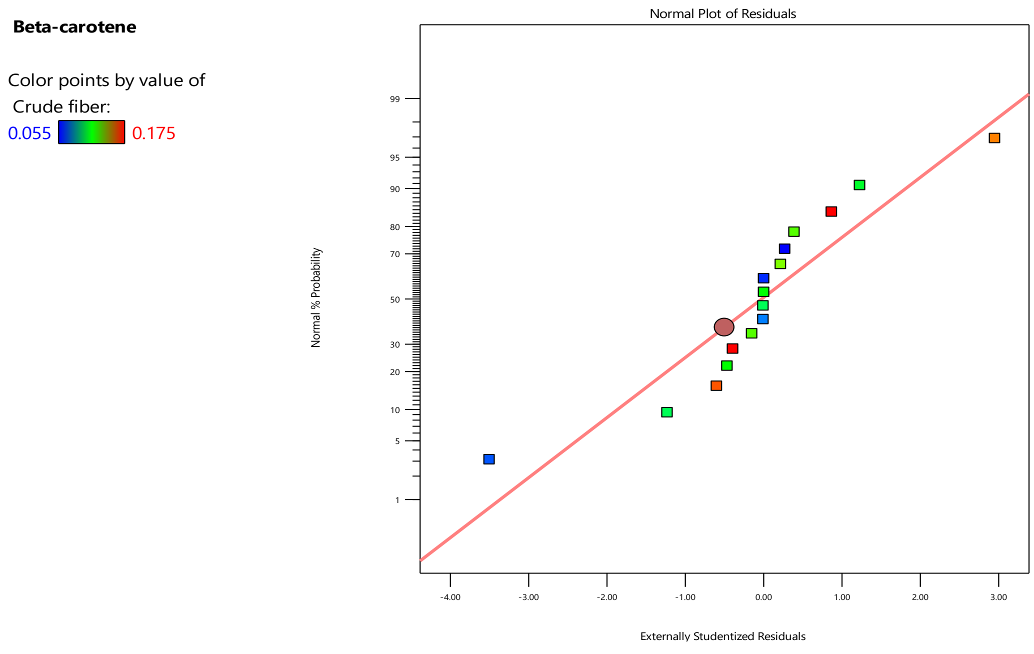

Figure 4.19: Normal plot against residuals for Beta-carotene

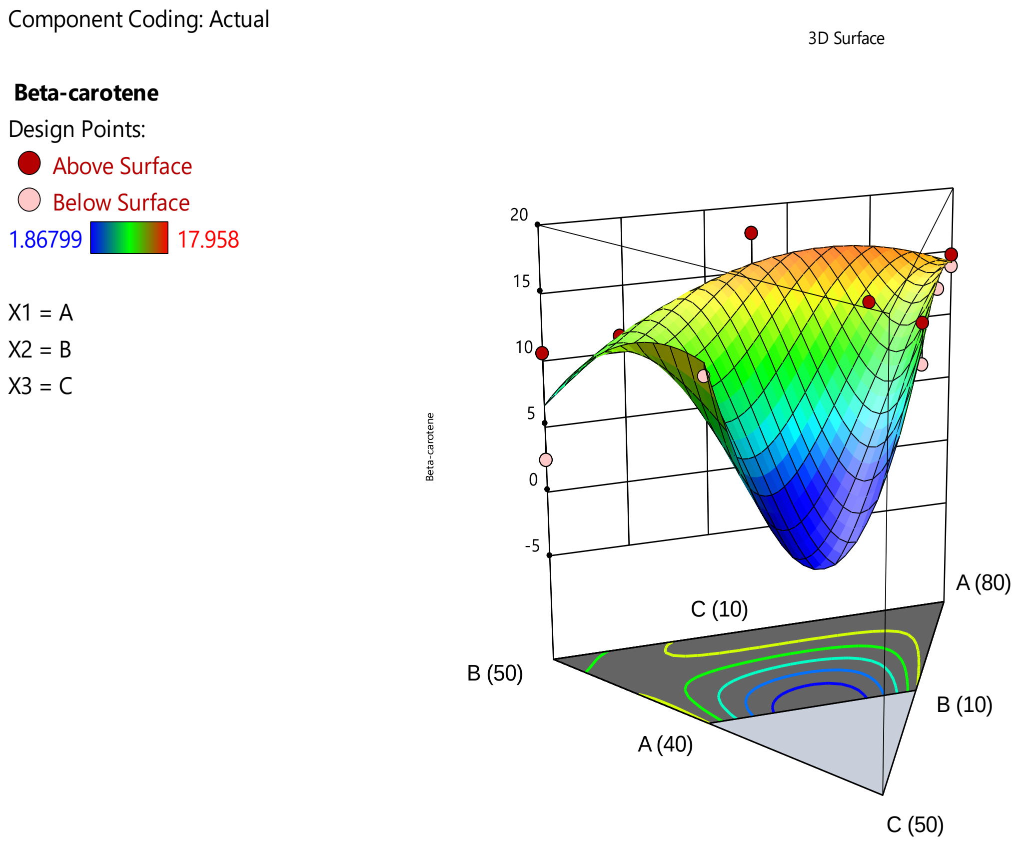

Figure 4.20: Response surface diagram for Beta-carotene

4.3.0 Optimization Conditions

The optimization constraints or criteria for the fortified blend from nixtamal maize flour, sweet potato flour and egg flour are presented in Table 4.13

Table 4.13: Optimization constraints

Name	Goal	Lower Limit	Upper Limit	Lower Weight	Upper Weight	Importance
A: Maize flour	is in range	40	80	1	1	3
B: Sweet Potato flour	is in range	10	50	1	1	3
C: Egg flour	is in range	10	30	1	1	3
Moisture content	minimize	3	18	1	1	3
Crude fibre	maximize	0.055	0.175	1	1	3
Fat content	minimize	7.24638	11.6364	1	1	3
Ash content	maximize	3	13.5	1	1	3
Crude protein	maximize	1.2	3.2	1	1	3
Carbohydrate	minimize	60.1886	79.9522	1	1	3
Water absorption capacity	maximize	12	20	1	1	3
Oil absorption capacity	minimize	10	16	1	1	3
Swelling capacity	maximize	12	26	1	1	3
Beta-carotene	maximize	1.86799	17.958	1	1	3

Table 4.14a: Solutions of the optimization result

No	Maize flour	Sweet Potato flour	Egg flour	MC	Fibre	Fat	Ash	protein
1	**71.771**	**13.727**	**14.503**	**5.869**	**0.108**	**9.55**	**10.967**	**2.198**
2	66.468	10	23.532	8.905	0.166	10.427	13.481	2.578
3	40	30	30	12.864	0.12	10.183	6.742	2.531
4	77.599	12.401	10	4.104	0.1	9.235	5.018	2.053
5	40	48.916	11.084	7.379	0.12	7.92	5.943	1.578

Table 4.14b: Solutions of the optimization result

No	CHO	WAC	OAC	SC	Beta-carotene	Desirability	
1	**70.765**	**17.099**	**13.124**	**20.997**	**13.998**	**0.582**	**Selected**
2	69.696	15.775	13.282	17.434	14.728	0.571	
3	66.783	14.587	10.609	20.807	13.346	0.513	
4	78.926	17.792	10.947	20.874	15.013	0.437	
5	76.73	17.241	13.212	23.492	7.582	0.436	

Where MC, CHO WAC, OAC and SC represents; moisture content, carbohydrate, water absorption capacity, oil absorption capacity and swelling capacity.

After optimization, five (5) solutions were found with desirability indices and the best that can be used for *masa* production selected. In Table 4.12, the desirability index of 0.582 was selected. This implies that the mixture percentage of nixtamal maize flour at 71.771, sweet potato flour at 13.727 and egg flour at 14.503 is the best which was used for *masa* production.

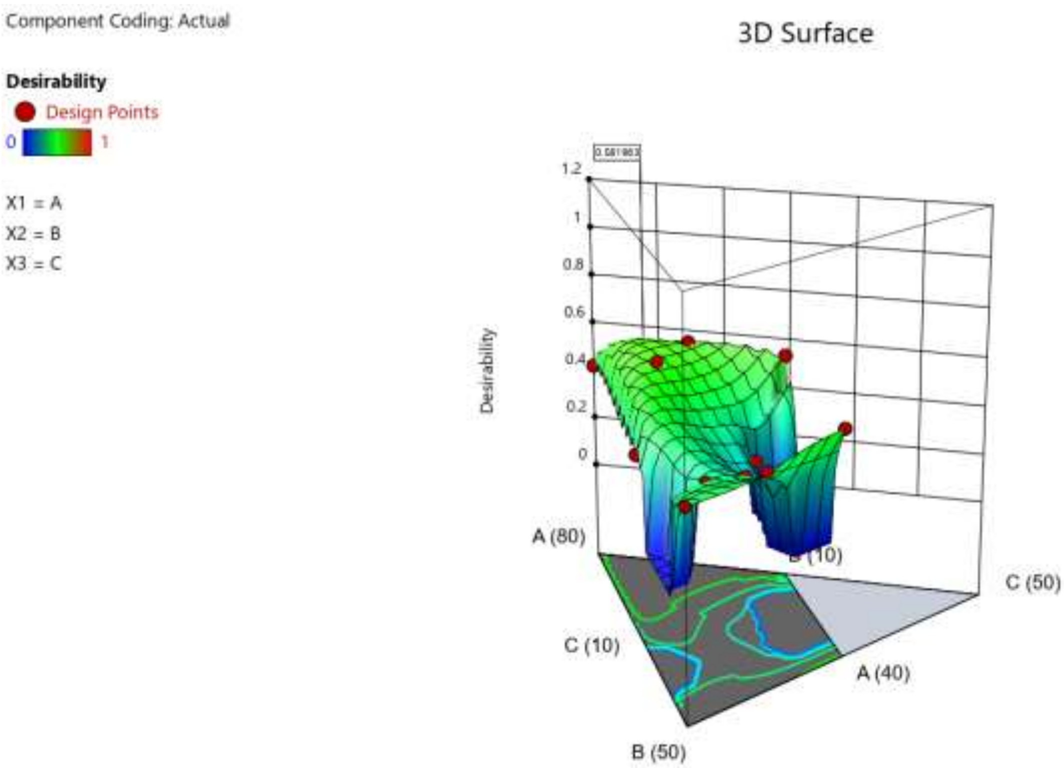

Figure 4.21: Response surface mixture graph for desirability index

4.4 Physical Properties of Rice, Fortified and Maize *Masa*

The physical properties of the rice, fortified and maize *masa* is presented in Table 4.15 with the analysis of variance (ANOVA) in Table 4.16.

Table 4.15: Physical Properties of Rice, Fortified and Maize *masa*.

	Rice	Fortified	Maize
Av. Loaf volume(cm^3)	71.94 ± 0.02^{a}	102.21 ± 0.007^{c}	98.27 ± 0.008^{b}
Weight(g)	28.16 ± 0.02^{a}	$64.83\pm.01^{c}$	$54.03\pm.027^{b}$
Length(cm)	6.22 ± 0.002^{a}	7.52 ± 0.008^{c}	7.22 ± 0.02^{b}
Thickness(cm)	2.02 ± 0.004^{b}	2.00 ± 0.004^{a}	2.10 ± 0.004^{c}
Width(cm)	$5.82\pm.005^{a}$	6.83 ± 0.006^{c}	6.50 ± 0.005^{b}
Loaf volume index(cm^3/g)	2.54 ± 0.1^{c}	1.58 ± 0.1^{a}	1.82 ± 0.005^{b}

All values are means of three replicates ± standard deviation. Means with same letters for a particular measurement along the same row are not significantly different ($p\leq0.05$)

Table 4.16: Analysis of variance (ANOVA) for the physical properties of rice, fortified and maize *masa*.

		Sum of Squares	**Df**	**Mean Square**	**F**	**Sig.**
Av. Loaf volume	Between Groups	1624.784	2	812.392	3739911.75	.000
	Within Groups	.001	6	.000		
	Total	1624.785	8			
Weight	Between Groups	2131.193	2	1065.596	2647078.93	.000
	Within Groups	.002	6	.000		
	Total	2131.195	8			
Length	Between Groups	2.785	2	1.393	10888.390	.000
	Within Groups	.001	6	.000		
	Total	2.786	8			
Thickness	Between Groups	.018	2	.009	655.008	.000
	Within Groups	.000	6	.000		
	Total	.018	8			
Width	Between Groups	1.596	2	.798	33399.474	.000
	Within Groups	.000	6	.000		
	Total	1.596	8			
Loaf volume index	Between Groups	1.520	2	.760	7860.043	.000
	Within Groups	.001	6	.000		
	Total	1.520	8			

4.4.1 Average loaf volume

The average loaf volumes of all the three *masa* were evaluated to be; rice *masa* 71.94cm^3, fortified *masa* 102.21 cm^3 and maize *masa* 98.27 cm^3. The result is similar to Ayo *et al.*, (2008) with average loaf volume of 129.5 cm^3 for maize fortified *masa* with rice. Slight differences might be as a result of different choice of component mixture used in the production of *masa*. Also, nixtamalization as a process which involves heating of maize flour in the presence of lime might contribute to differences in average loaf volume of the *masa* produced. Fortified *masa* had the highest value of loaf volume among. However, the analysed result was significant at $p \leq 0.05$.

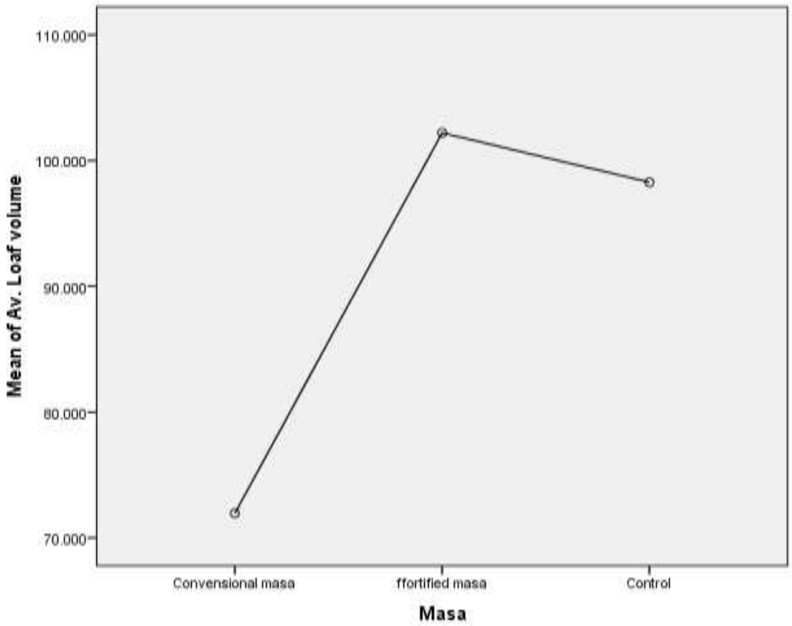

Figure 4.22: Mean of av. Loaf volume plot for rice, fortified and maize *masa*

4.4.2: Weight

This is the measure of quantity of matter or force with which the earth attracts the product to the centre of the earth. It is a property of *masa* that quantifies its value numerically how much it weighs. The rice, fortified and maize *masa* had the weight of 28.16g, 64.83g and 50.03g respectively. According to Ayo *et al.* (2008) the weight of the rice, maize and millet *masa* is 79g, 81g, and 88g. The result is not similar to Ayo *et al.*, (2008) because of the intended target of the research that had a goal of 60g *masa* target. Also, the different component mixture of nixtamal maize flour, sweet potatoes flour and egg flour have a more denser particle nucleus that will make *masa* have more weight. Fortified *masa* have more weight that is significantly acceptable compared to both rice and maize *masa*.

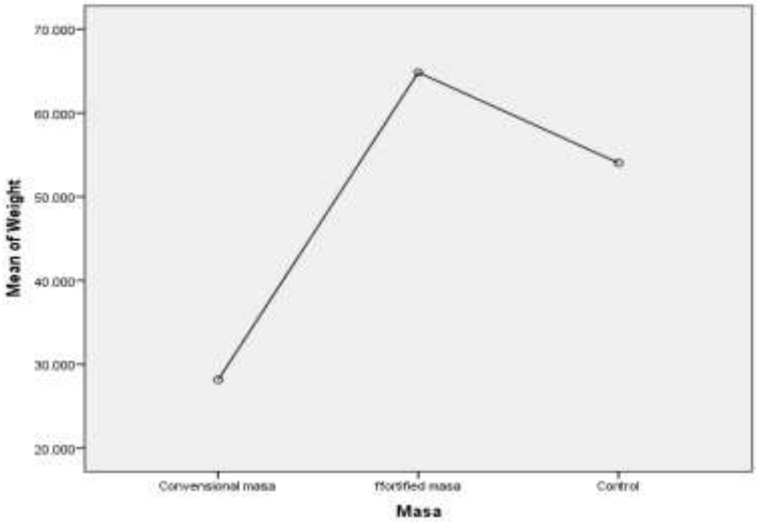

Figure 4.23: Mean of weight plot for rice, fortified and maize *masa*

4.4.3 Length

The length of the rice, fortified and maize *masa* as presented in Table 4.15 are 6.22cm, 7.53cm and 7.22cm. Fortified *masa* had the longest length followed by maize *masa* and rice *masa*. The result of the fortified and maize *masa* is not different from Ayo *et al.*, (2008) that studied on the effect of different cereals on the quality of *masa.* Slight differences might be attributed to the nature of the cup-like depression pan used in the production of *masa* as well as the different component mixture used for the production of *masa*.

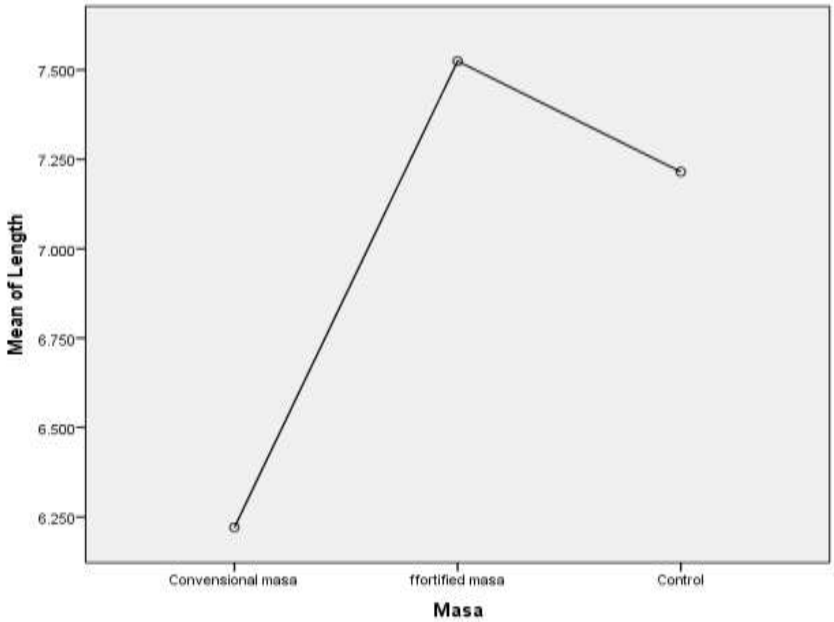

Figure 4.24: Mean of Length plot for rice, fortified and maize *masa*

4.4.4 Thickness

The thickness of *masa* is a measure of its ability to rise, the result obtained from Table 4.15 showed that the rice *masa* had a thickness of 2.02cm, fortified *masa* (2.00cm) and maize *masa* 2.10cm. The result showed that the rice *masa* thickness was higher than that of fortified *masa* because of variation in the quantity of yeast added. However, the degree of variation was within the acceptable range with $p< 0.05$.

4.4.5 Width

The result of the rice, fortified and maize *masa* as presented in Table 4.15 are 5.82cm, 6.83cm and 6.50cm. The results of the analysis showed that all the produced *masa* were significant at $p\leq0.05$. Fortified *masa* had the widest width due to its length and thickness. Also, the quantity of yeast added during frying of *masa* can have effect on the width of the *masa*.

4.4.6 Loaf volume index

The loaf volume index of the rice, fortified and maize *masa* as presented in Table 4.15 are 2.54 cm^3/g, 1.58 cm^3/g, 1.82 cm^3/g. The obtained result is similar to that of Ayo *et al.,* (2008). All the results were significant at ($p \leq 0.05$) with rice *masa* been highest in loaf volume index.

4.5 Sensory Properties of fortified, Rice and Maize *Masa*

The sensory properties of fortified, rice and maize *masa* are presented in Table 4.18.

Table 4.17: Sensory Properties of Fortified, Rice and Maize *Masa*

Masa	**Colour**	**Taste**	**Mouth-feel**	**Appearance**	**Gen. acceptance**
Rice	7.00 ± 0.71^{ab}	7.40 ± 0.54^{ab}	7.20 ± 1.1^{a}	7.80 ± 1.3^{a}	7.20 ± 0.33^{b}
Fortified	7.00 ± 0.84^{b}	8.20 ± 0.84^{b}	8.00 ± 1.0^{a}	7.80 ± 0.9^{a}	8.15 ± 0.37^{c}
Maize	5.80 ± 1.1^{a}	6.80 ± 0.84^{a}	6.80 ± 1.6^{a}	7.20 ± 0.84^{a}	6.50 ± 0.50^{a}

All values are means of three replicates ± standard deviation. Means with same letters for a particular measurement along the same row are not significantly different ($p \leq 0.05$)

The result from the comparison of the three *masa* showed that both the rice and fortified *masa* had the same means score for colour (7.00 each). This implies there was no significant difference at p = 0.05. The good colour might be as a result of the alkaline cooking that is known to improve colour and nutritional value as well as gelatinization. This result is not different from that of Ayo *et al.,* (2008) with mean score value from the range of 2.53 – 8.80. The mean score for taste is between 6.80 – 8.20, the panellist result showed that the interest of the populace was towards liking nixtamal *masa* fortified with sweet potatoes and egg flour. This might be as a result of the improved nutritional content of *masa* through fortification. The averages mean score result for taste is similar and within range with the work of Ayo *et al.* (2008) that is within 5.27 – 8.40.

The mouths feel result range from 6.80 – 8.00 with *masa* produced from maize flour, sweet potatoes flour and egg being the highest. This result is statistically significant – meaning the fortified *masa* was acceptable. From the statistical analysis and data obtained, the appearance of both the rice and fortified *masa* is same with mean score of 7.80 respectively. The significant effect of fortified *masa* showed it similarity to rice *masa* but with a slight difference.

General acceptability of *masa* is a function of the overall quality indices of the rice, fortified and maize *masa*. Analysed result showed that fortified *masa* from nixtamal maize flour, sweet potatoes flour and egg flour is highly accepted with a mean score of 8.15, followed by rice *masa* 7.20. Plate V, VI and VII represent fortified, rice and maize *masa*.

Plate V: Fortified *Masa*

Plate VI: Rice *masa*

Plate VII: Maize *masa*

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The following conclusions are made from this study

1. Nixtamilization process increased the moisture content, fibre, fat and swelling capacity significantly but decreased the ash, protein, carbohydrate, water absorption capacity, oil absorption capacity and beta-carotene significantly.

2. The proximate and functional properties of nixtamal maize flour, sweet potatoes flour and egg flour indicate that *masa* can be fortified with appropriate selected component of choice.

3. The optimum condition for fortified *masa* production is 71.8% nixtamal maize flour, 14.5% egg flour and 13.72% sweet potatoes flour with a desirability index of 0.582.

4. The evaluated properties of the physical and sensory properties showed that fortified *masa* had the highest mean scores and was acceptable.

5. Fortified *masa* was accepted in terms of general acceptability compared to conventional *masa*.

5.2 Recommendations

Based on the findings of the obtained result;

i. Fortified nixtamal *masa* flour is recommended for its nutritional qualities and reduced time taken in the production of *masa* compare to the normal conventional method.

ii. Further studies should be carried out on the storage stability of the fortified *masa* flour.

iii. Further studies should be carried out on the mineral content of the fortified *masa* flour.

iv. Fortification of *masa* with other mixture components should be carried out to determine the nutritional properties of the flour.

5.3 Contribution to Knowledge

This research has contributed to knowledge in the following;

1. Provided the optimum condition for fortified *masa* production; 71.8% nixtamal maize flour, 14.5% egg flour and 13.72% sweet potatoes flour with a desirability index of 0.582.
2. The research tackled malnutrition deficiency through the concept of food fortification using nixtamal maize flour in the production of fortified instant *masa* flour with sweet potato and egg that will be readily available.
3. Use of agricultural crops as vehicles and fortificant in alternative to chemical fortificant that are costly.
4. Development of models that can be used for prediction.

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APPENDIX A

Table 4.1: Descriptive analysis for the physical properties of Rice, Fortified and Maize *masa*.

Descriptives

						95% Confidence Interval for Mean			
		N	**Mean**	**Std. Deviation**	**Std. Error**	**Lower Bound**	**Upper Bound**	**Minimum**	**Maximum**
Av. Loaf volume	Rice masa	3	71.94233	.022679	.013094	71.88600	71.99867	71.925	71.968
	fortified masa	3	102.20800	.007810	.004509	102.18860	102.22740	102.203	102.217
	Maize masa	3	98.27267	.008737	.005044	98.25096	98.29437	98.263	98.280
	Total	9	90.80767	14.251251	4.750417	79.85319	101.76215	71.925	102.217
Weight	Rice masa	3	28.15500	.019000	.010970	28.10780	28.20220	28.134	28.171
	fortified masa	3	64.83033	.010599	.006119	64.80400	64.85666	64.819	64.840
	Maize masa	3	54.02833	.027099	.015645	53.96102	54.09565	54.000	54.054
	Total	9	49.00456	16.321746	5.440582	36.45855	61.55056	28.134	64.840
Length	Rice masa	3	6.22067	.002517	.001453	6.21442	6.22692	6.218	6.223
	fortified masa	3	7.52467	.008737	.005044	7.50296	7.54637	7.515	7.532
	Maize masa	3	7.21500	.017349	.010017	7.17190	7.25810	7.200	7.234
	Total	9	6.98678	.590103	.196701	6.53318	7.44037	6.218	7.532
thickness	Rice masa	3	2.01967	.003512	.002028	2.01094	2.02839	2.016	2.023
	fortified masa	3	2.00100	.003606	.002082	1.99204	2.00996	1.998	2.005
	Maize masa	3	2.10433	.004041	.002333	2.09429	2.11437	2.100	2.108
	Total	9	2.04167	.047799	.015933	2.00493	2.07841	1.998	2.108
width	Rice masa	3	5.81667	.004509	.002603	5.80547	5.82787	5.812	5.821
	fortified masa	3	6.82633	.005508	.003180	6.81265	6.84001	6.821	6.832
	Maize	3	6.50400	.004583	.002646	6.49262	6.51538	6.500	6.509
	Total	9	6.38233	.446640	.148880	6.03902	6.72565	5.812	6.832

Loaf volume index	Rice masa	3	2.54433	.010970	.006333	2.51708	2.57158	2.532	2.553
	fortified masa	3	1.57667	.012014	.006936	1.54682	1.60651	1.565	1.589
	Maize masa	3	1.82067	.005033	.002906	1.80816	1.83317	1.816	1.826
	Total	9	1.98056	.435917	.145306	1.64548	2.31563	1.565	2.553

Table 4.2 Analysis of Variance (ANOVA) Sensory Properties of Fortified, Rice and Maize *Masa*

		Sum of Squares	**Df**	**Mean Square**	**F**	**Sig.**
Colour	Between Groups	14.400	2	7.200	9.000	.004
	Within Groups	9.600	12	.800		
	Total	24.000	14			
Taste	Between Groups	4.933	2	2.467	4.353	.038
	Within Groups	6.800	12	.567		
	Total	11.733	14			
Mouth feel	Between Groups	3.733	2	1.867	1.143	.001
	Within Groups	19.600	12	1.633		
	Total	23.333	14			
Appearance	Between Groups	4.933	2	2.467	2.312	.001
	Within Groups	12.800	12	1.067		
	Total	17.733	14			
General acceptance	Between Groups	6.970	2	3.485	21.071	.000
	Within Groups	1.985	12	.165		
	Total	8.955	14			

Table 4.3: Descriptive analysis for Sensory Properties of Fortified, Rice and Maize *Masa*

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Colour	Rice masa	5	7.000	.7071	.3162	6.122	7.878	6.0	8.0
	Fortified masa	5	8.200	.8367	.3742	7.161	9.239	7.0	9.0
	Maize masa	5	5.800	1.0954	.4899	4.440	7.160	4.0	7.0
	Total	15	7.000	1.3093	.3381	6.275	7.725	4.0	9.0
Taste	Rice masa	5	7.400	.5477	.2449	6.720	8.080	7.0	8.0
	Fortified masa	5	8.200	.8367	.3742	7.161	9.239	7.0	9.0
	Maize masa	5	6.800	.8367	.3742	5.761	7.839	6.0	8.0
	Total	15	7.467	.9155	.2364	6.960	7.974	6.0	9.0
Mouth feel	Rice masa	5	7.200	1.0954	.4899	5.840	8.560	6.0	8.0
	Fortified masa	5	8.000	1.0000	.4472	6.758	9.242	7.0	9.0
	Maize masa	5	6.800	1.6432	.7348	4.760	8.840	5.0	9.0
	Total	15	7.333	1.2910	.3333	6.618	8.048	5.0	9.0
Appearance	Rice masa	5	7.800	1.3038	.5831	6.181	9.419	6.0	9.0
	Fortified masa	5	8.600	.8944	.4000	7.489	9.711	7.0	9.0
	Maize masa	5	7.200	.8367	.3742	6.161	8.239	6.0	8.0
	Total	15	7.867	1.1255	.2906	7.243	8.490	6.0	9.0
General acceptance	Rice masa	5	7.2480	.32958	.14739	6.8388	7.6572	6.83	7.75
	Fortified masa	5	8.1480	.36561	.16351	7.6940	8.6020	7.75	8.75
	Maize masa	5	6.4800	.50388	.22534	5.8543	7.1057	5.91	7.16
	Total	15	7.2920	.79977	.20650	6.8491	7.7349	5.91	8.75