CHARACTERISATION OF EKPOMA RICE (*Oryza glaberrima)*

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(BIOTECHNOLOGY TECHNIQUES)

FACULTY OF LIFE SCIENCES

UNIVERSITY OF BENIN

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A PROJECT WORK SUBMITTED TO THE DEPARTMENT OF NATURAL SCIENCE, FACULTY OF SCIENCE LABORATORY TECHNOLOGY, UNIVERSITY OF BENIN, BENIN CITY, EDO STATE, NIGERIA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR DEGREE (B.sc) IN SCIENCE LABORATORY TECHNOLOGY.

(BIOTECHNOLOGY TECHNIQUES)

NOVEMBER, 2025.

CERTIFICATION

This is to certify that this project work titled "**Characterisation of Ekpoma rice (*Oryza glaberrima)*** was completed by **Sandra Ese OKUNZUWA (miss)** with matriculation number **LSC2007332,** Department of Science Laboratory Technology (Biotechnology Techniques), Faculty of Life Sciences, University of Benin, Benin City.

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DECLARATION

I declare that the project work **"Characterisation of Ekpoma rice (*Oryza glaberrima)*"** was written by me in the Department of Science Laboratory Technology (Biotechnology Techniques), University of Benin, Benin City, Edo state.

_____ _____

Sandra Ese OKUNZUWA (Miss). **DATE**

(Student)

DEDICATION

This project is dedicated to God Almighty, my caring family and my small circle of friends for their unfailing love and support over the years.

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First, my sincere gratitude goes to God Almighty for his constant guidance, provision, unwavering love and protection through my stay in the University of Benin.

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My special thanks goes to my dear Mum, Mrs. Rita Okunzuwa, Daddy Olivet, my loving sister, sis Eva, my elder brother, Pastor Kingsley, and the rest of my entire siblings, for their unfailing love, words of encouragement and support.

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ABSTRACT

Ekpoma rice is a native rice grown in Esan Land and it is believed to be rich in fibre, carbohydrate, protein, crude fat, and favorable nutritional content. Ekpoma rice is an important source of carbohydrate. The rice flour was stored for 0-3 months to investigate possible storage changes in the nutritional content of the rice flour. The proximate, mineral analysis and amino-acid profile was done using standard methods such as AOAC methods. Kjeldahl procedure was used to determine the crude protein in the rice. Determination of the minerals was carried out using Nitric-perchloric acid digestion and the amino-acid analysis was carried out using an amino-acid analyzer. Results show it contains (81.65-82.52%) carbohydrate, (5.53-5.89%) protein, (0.75-1%) crude fat, (0.08-0.47%) crude fibre, (0.31-0.67%), ash content, (9.60-11.00%) moisture content and (932.00-948%), nitrogen. Mineral analysis shows it is rich in phosphorus(P), potassium(K), calcium (Ca), magnesium (Mg), zinc (Zn), copper (Cu), iron (Fe), and manganese (Mn). The amino-acid analysis shows that it is rich in both essential and non-essential amino-acids. The essential amino-acids includes lysine, leucine, isoleucine, histidine, methionine, methylalanine, threonine, tryptophan and valine. The nutritional content of Ekpoma rice bran is comparable rich bran, therefore, it can be consumed by individuals with or without health issues.

CHAPTER ONE

1.0 INTRODUCTION

Rice (*Oryza sativa*) is an important crop in the world both as a staple food and as a cash crop (Hill and Waller, 1999). In Nigeria, it's reported that 1,642,000 ha of rice were grown in 1996 out of which 48% of the land and 53% of the production were rain-fed. Rain-fed lowland rice is the most widespread system and accounts for approximately half of the total rice area in Nigeria (UNEP, 2005). Ekpoma, located in the lowland humid forests of Nigeria (Segynola, 1992), is the headquarters of Esan West Local Government Area of Edo State, Nigeria and is the only rice-producing community in Esanland which had a population of 372,122 people or 17.13% of the population of Edo State in 1991 (NBS, 2006). Rice is rain-fed in Ekpoma and it is an important crop in the farming system of the people as it features prominently in most of the traditional festivals in the area. About 20% of rice production in Edo State was from Ekpoma in the 1980s and early 1990s (Edo State Agricultural Development Programme, unpublished), but United Nations Environment Programme (UNEP,2005) reported a decline in rice production in the State, which calls for urgent measures to check this trend. Although, the rice production system depended largely on the local variety of the African rice, *Oryza glaberrima*, popularly called 'Ekpoma rice', several new varieties of *O. sativa* such as FAR 11, OS 6 and ITA 150 have been introduced into the system in recent times. These new varieties have virtually replaced the local variety, but they require the application of fertilizer and other improved crop management practices for optimal yield. It's reported that these crop management practices aggravate insect pests' problems which constitute one of the major constraints to production (Oka *et al.,* 1979) . It's also reported that insect pests cause 30– 100% crop loss on rice (Umeh *et al.,* 1991). About 138 insect pest species as well as 22 species of parasitoids and predators have been recorded on rice in Nigeria (Jerath, 1965) The abundance and distribution of these insects; however,

depend on the ecological zone and rice production system (Umeh *et al.,* 1992). Ukwungwu and Joshi (1990) reported that the prevalent insect pests of rice in southwestern Nigeria were termites and *Diopsis* species. Not much has been reported in the literature on the insect pest complex of rice in Ekpoma.

Rice is a cereal crop that belongs to the grass species *Oryza sativa* (Asian rice) or *Oryza glaberrima* (African rice). It has grown in popularity in recent years and is one of the most consumed cereal grain in the world. Rice ranked as the third-highest agricultural commodity with worldwide production as follows when compared with other staple crops (FAOSTAT, 2016). Rice (*Oryza sativa*) is a staple food in many parts of the world and in many countries of Africa, *Oryza glaberrima* (African rice) as become popular among the people which make rice important staple food for about half of the human race.

Research over the years has shown that rice production and processing technologies have not been able to meet the increasing demand for rice (Saka *et al.,* 2009). There are three varieties of rice and these include; long-grained, medium-grained, and short-grained rice. The long grain rice has high in amylose content and the grain tends to remain intact after cooking; medium-grain rice has high in amylopectin content and it becomes stickier on cooking (Adeyeye *et al.,* 2018). West African nations had experienced unprecedented importation of rice in the last three decades. Much of these importations of rice to West African sub-region are from South East Asia, where rice has been on large scale. Rice has the potential to improve nutrition, boost food security, foster rural development and support sustainable land use in Africa if its cultivation is boosted and improved upon (Jones, 1995). In Nigeria, rice is important to the people due to several reasons which include being a major contributor to internal and sub-regional trade (Horna *et al.,* 2005). Two types of rice have been mainly cultivated in Nigeria: the African rice (*Oryza glaberrima*) and the Asian rice (*Oryza sativa*).

Ekpoma rice is a variety of rice native to Ekpoma, a town in Edo State, Nigeria. It's known for its short-grained, and sweet flavor, which is a point of differentiation from other Nigerian rice varieties (Adeyeye, 2018). Ekpoma rice, a Native Nigerian variety, offers several nutritional benefits, particularly when it is consumed in its unpolished form. Ekpoma rice are a good source of carbohydrates, protein, healthy fat, fiber, vitamins such as vitamin B_1(thiamine), vitamin B_2(riboflavin), vitamin B_3(niacin), vitamin A and vitamin E, amino acids, and heavy metals. The fiber content in Ekpoma rice supports digestive health and aid in cholesterol management (Horna *et al.,* 2005). The level of heavy metals such as arsenic, lead, cadmium, mercury, and chromium in Ekpoma rice are below the maximum acceptable limits, indicating it's safe for consumption. The antioxidants, such as vitamin A and E provide antioxidants benefits, protecting cells from oxidative stress (Olalekan *et al.,* 2019).

1.1 STATEMENT OF THE PROBLEM

Ekpoma rice is a unique variety of white unpolished Nigerian rice. It is very nutritious with a moderate glycemic index which can help to ameliorate these health issues. High consumption of white rice has been found to be associated with significantly increased risk of type-2 diabetes and excess weight gain especially in Nigerians and Asians. It is believed that the risk of type-2 diabetes was increased by 59% in women and 37% in men. In addition, the starch content of rice is the major determinant of its glycemic index (GI). Starch is the most abundant carbohydrates in cereals, roots and tubers and plays a special role in glucose homeostasis (Mann *et al.,* 2007). Consumption of easily digestible food results in rapid rise in blood glucose and substantial fluctuation of hormones, which places high stress on the regulatory system (Ludwig *et al.,* 2002). Physical, chemical, and enzymatic methods, however, may be used to modify the molecular structure of starch thereby delaying its rate of digestion. (Lee *et al.,* 2008).

Research has shown that rice constitutes about 6-10% protein, which has a relatively high protein efficiency ratio (PER) of 2.18, almost equivalent to that of beef (2.30), a considerably more costly protein source (Tawheed *et al.,* 2017). Efforts have therefore been made to improve the protein level in rice involving the selective breeding of new rice varieties, but it did not improve the protein content to the extent that it could be used in rice-based infant formula or other protein-enriched/fortified foods. Another approach has been to increase the protein content of rice flour by gelatinizing and enzymatically digesting rice starch with carbohydrates commonly known as amylases. (Tawheed *et al.,* 2017).

Rice, however, have lower shelf stability than their respective grain forms due to the increased surface area available for moisture absorption and other deteriorative changes often influenced by storage time and environmental conditions (Hruskova and Machova, 2002). Rice has a commendable shelf life compared to other varieties. The longevity of rice largely depends on the conditions it's stored under. Unopened and stored in a cool, dry place, rice can maintain its quality for up to 2 years. Once opened, its freshness is typically best preserved for 6 to 12 months. The transfer of moisture or oxygen can be controlled by thermodynamic and dynamic processes. The storage stability study of rice is a primary function of air (oxygen) diffusion, moisture content migration and water activity (Cenkowski *et al.,* 2000).

The quality of rice can be compromised over time, leading to it turning rancid. Indicators of spoilage are a sour smell, a change in color, or a clumpy texture, which signal that the rice should not be used. To ensure maximum freshness, it's adviced to store rice in an airtight container away from any sources of moisture and heat, which can accelerate its deterioration. Packaging is a means of providing the correct and stable environmental conditions for food during storage and the choice of materials for packaging depends on the nature of the product, the storage and handling conditions (temperature, humidity, risk of physical deterioration)

among other factors (Brown, 1992). Low-density polyethylene (LDPE) is a heat sealable, inert, odor free and shrinks when heated. It is a good moisture barrier but has relatively high gas permeability, sensitivity to oils and poor odor resistance. LDPE is widely used because it is among the most available and affordable packaging material.

1.2 AIM OF THE STUDY

To determine the possible changes in the proximate composition, mineral elements and also the amino-acid profile of Ekpoma rice stored over a period of time.

1.3 OBJECTIVES OF THE STUDY

1. To determine the proximate analysis of Ekpoma rice.
2. To determine the mineral elements in Ekpoma rice.
3. To determine the amino acid present in Ekpoma rice.
4. To investigate storage changes in the rice sample over a period of time.

CHAPTER TWO

LITERATURE REVIEW

2.0 EKPOMA RICE

Ekpoma rice, commonly known as the African rice in Nigeria, refers to a cereal crop that belongs to the grass species *Oryza glaberrima*.(Adeyeye, 2018). Generally, Ekpoma rice grains belongs to the genus Oryza of the Poaceae Family(formally Graminae) which includes twenty wild species and two cultivated ones, *Oryza sativa* (Asian rice) and *Oryza glaberrima* (African rice). (Linares *et al.,* 2002). Rice, belonging to the *Oryza* genus, is a vital crop that plays a significant role in global food security, making it a highly valuable commodity worldwide. The genus comprises two main domesticated species: *Oryza sativa*, which originated in Asia, and *Oryza glaberrima*, which was domesticated in Africa.

Recent archaeological evidence suggests a third domestication event may have occurred in the Amazon (Hilbert *et al.,* 2017). Although *O. glaberrima* is mainly cultivated in West Africa, there is evidence of this species in the Suriname where it is believed to have been distributed by enslaved Africans (van Andel *et al.,* 2016). African rice possesses immense genetic potential in terms of resistance to biotic and abiotic stress and therefore forms a valuable genetic resource for rice improvement (Wambugu *et al.,* 2013). Due to its importance, the origin and evolution of rice has been extensively studied over the past several decades using archaeological, linguistic, isozyme, molecular and morphological evidence (Stein *et al.,* 2018). Although, research has been conducted, the origins, evolutionary history, and domestication of *Oryza sativa* and *Oryza glaberrima* remain unclear and are topics of ongoing debate. The domestication history of African rice is less disputed compared to Asian rice. Furthermore, African rice has received significantly less attention in terms of research on its origins and domestication.

However, over the last few years there has been renewed interest in using whole genome data to unravel this complex domestication history (Veltman *et al.,* 2019). This renewed interest was likely sparked by the development of affordable DNA sequencing technologies. Major advances in genetics and genomics have been recorded for African rice and *O. barthii*, its putative progenitor over the last couple of years (Stein *et al.,* 2018). Over 500 whole genome sequences of African rice and *O.barthii* are now publicly available, offering a valuable resource for studying the origin and domestication history of this crop. The models, knowledge and insights obtained for Asian rice remain invaluable and continue to guide domestication studies in African rice (Purugganan., 2019). The rice plant, a monocot, typically grows to a height of 1-1.18 meters (3.3-5.9 feet), with variations depending on the specific variety and soil conditions. It has long slender leaves 50-100cm (20-39in) long and 2-2.5 cm (0.79-0.98in) broad. (Saka *et al.,* 2009). Rice produces wind-pollinated flowers in clusters, known as inflorescence, which can range from 30-50cm (12-20 inches) in length and having an arching or pendulous shape. The rice is a cereal and the seed is a caryopsis which is 5-12 mm long and 2-3 mm thick. (Adeyeye *et al.,* 2018). Ekpoma rice (*Oryza glaberrima*) also called African rice, has become popular among people which makes rice an important staple food for about half of the human race (USA Rice Federation., 2002). According to the National Research Council, rice is a vital crop that provides sustenance for over half of the world's population. Given its growing importance, the Food and Agriculture Organization (FAO) predicts a 50% increase in rice production will be needed to meet future global demand. Ekpoma rice, being in Nigeria, offers a variety of delicious rice dishes, with Jollof rice being a popular choice. Other common rice-based meals include Nigerian fried rice and Ofada rice with various stews.

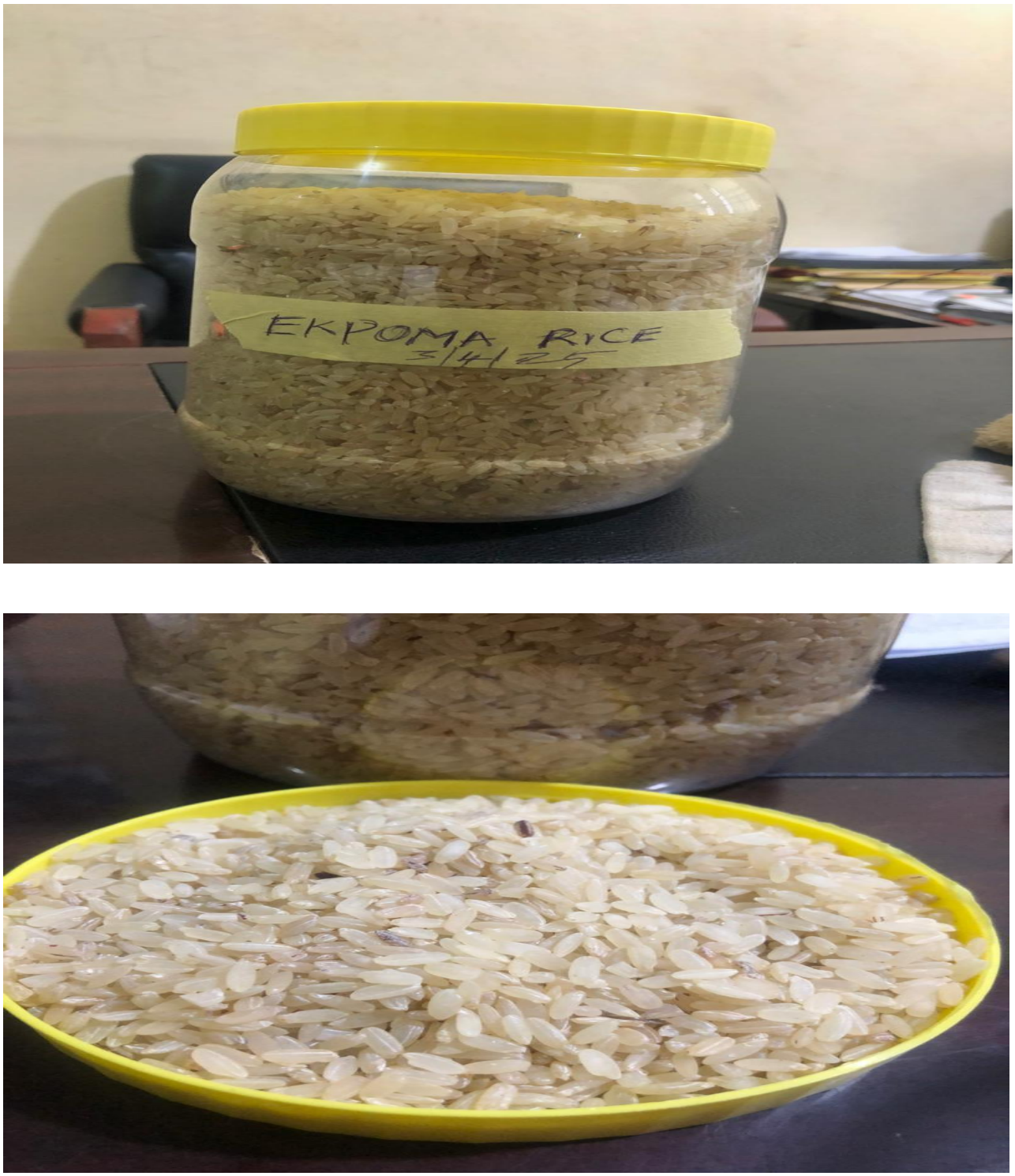

Fig: 1.1: Packed and Unpacked Ekpoma rice.

(Photo Credit: Okunzuwa., 2025)

2.1 White unpolished rice

Ekpoma rice is referred to as a "white unpolished rice" because, despite retaining its bran layer (making it unpolished), it has a lighter color compared to traditional brown rice. (Olalekan *et al.,*2019). The key factors contributing to its classification as "white unpolished rice" include:

Variety: Ekpoma rice is a specific type of rice that may have a naturally lighter color

Processing: while it's unpolished, the processing might not leave as much bran or germ intact as traditional brown rice.

This distinction doesn't diminish its nutritional value, as Ekpoma rice still offers nutritional benefits like higher protein and fiber content compared to polished white rice.

2.1.1 Composition of Ekpoma rice and its importance to humans

1. Carbohydrates

Ekpoma rice is a type of Nigerian rice variety with a carbohydrate composition of approximately 75.75% carbohydrates. Here's a breakdown:

Carbohydrate content: 75.75% ± 0.10

Starch: Main form of carbohydrate, broken down into glucose for energy

Fiber: 1.40% ± 0.02 crude fiber

Sugars: Minimal amount, includes glucose, sucrose, and dextrin. (Okpala *et al.,* 2017)

2. Protein

Ekpoma rice contains a considerable amount of protein, making it a valuable source of nutrition. Here's a breakdown of its protein composition:

Protein Content: 6.72% ± 0.05 of its total composition

Essential Amino Acids: Ekpoma rice contains various essential amino acids, including: Phenylalanine, leucine, valine, lysine, histidine, and threonine.

Non-Essential Amino Acids: Ekpoma rice also contains non-essential amino acids like: aspartic acid, serine, and alanine.

These indicate that Ekpoma rice is a good source of protein, although it may be deficient in certain amino acids like lysine. Nonetheless, its protein content contributes to its nutritional value as a staple food. (Olalekan *et al.,* 2019).

3. Fats

Ekpoma rice contains a relatively low amount of fat, with a fat composition of approximately 0.47% ± 0.03%. This value is based on a study assessing the nutritional composition and heavy metal profile of Nigerian rice varieties. (Olalekan *et al.,* 2019).

Table 2.1: Here's a better comparison with other Nigerian rice varieties:

Rice varieties	Fat content
Ofada rice:	0.50% ± 0.03%
Abakaliki rice:	0.54% ± 0.04%
Ekpoma rice:	0.47% ± 0.03%
Igbimo rice:	0.51% ± 0.03%

It's worth noting that the fat content in rice can vary depending on factors such as the type of rice, processing methods and environmental conditions. However, Ekpoma rice generally has a low fat content, making it a good option for those looking to manage their fat intake. (FAO, 1998).

4. Minerals

Ekpoma rice contains various minerals essential for human health. These includes; Iron, zinc, calcium, potassium, magnesium and sodium.

5. Vitamins

Ekpoma rice contains various vitamins essential for human health. Here's a breakdown of its vitamin composition:

Vitamin A: 160.0-341.79 IU, with some studies indicating values around 0.12-0.13 mg/100g.

Thiamine (Vitamin B_1): 0.11 mg/100g, with other rice varieties showing values around 0.25-0.27 mg/100g.

Riboflavin (Vitamin B_2): 0.04 mg/100g, with other rice varieties showing values around 0.027-0.037 mg/100g.

Niacin: Present, contributing to energy metabolism.

Vitamin C: Some studies indicate values around 6.46-6.87 mg/100g in rice-based foods.

Vitamin E: Present, with values around 0.40-0.43 mg/100g in rice milk.

It's worth noting that vitamin content can vary depending on factors such as rice variety, processing methods and storage conditions. (Olalekan *et al.,* 2016).

6. Water

The water composition of Ekpoma rice refers to its moisture content, which is approximately:

Moisture Content: 13.97% ± 0.10

This value is based on a study assessing the nutritional composition and heavy metal profile of Nigerian rice varieties. The moisture content can affect the rice's texture, shelf life and cooking properties. (Olalekan *et al.,* 2016).

2.12. Challenges of Rice Production in Central District of Edo State, Nigeria

2.13. Area of study

This study focuses on Esan Land (Edo State Central senatorial district) in Edo state, Nigeria, a region known for its significant rice production. Although, it was once a major rice-producing area, its role has diminished in recent times. The area is predominantly rural, with most residents engaged in farming, particularly rice and cassava cultivation (Omofonmwan, 1995). Esan area is the geographic unit situated between latitude 6o101’ and 6o 45’ North of the 4 Equator and between longitude 6o 10’ and 60 30’ East of the Greenwich Meridian (Fig. 2.1).

The relief of the region can broadly be divided into two structural components viz: the relatively undulating plateau surface which occupies about 75 percent of the area and the slopes and lowland and are to be found mostly in the southeast part of the region. This is the part of the region bordering the River Niger (Fig. 2.1& 2.2). These two structural components favour the cultivation of upland and swamp rice, respectively.

The soils in the area are ferrisols developed on loose sandy sediments. In the Northern part of the region, the soil appears reddish, while in the Southern part, they are yellowish-brown. These soils experience minimal leaching, making them favorable for cultivating crops such as rice. When freshly cleared from forested land, the topsoil contains approximately 5% organic matter, enabling it to support crop growth for several years without the need for fertilizer. (Akinbode, 1983).

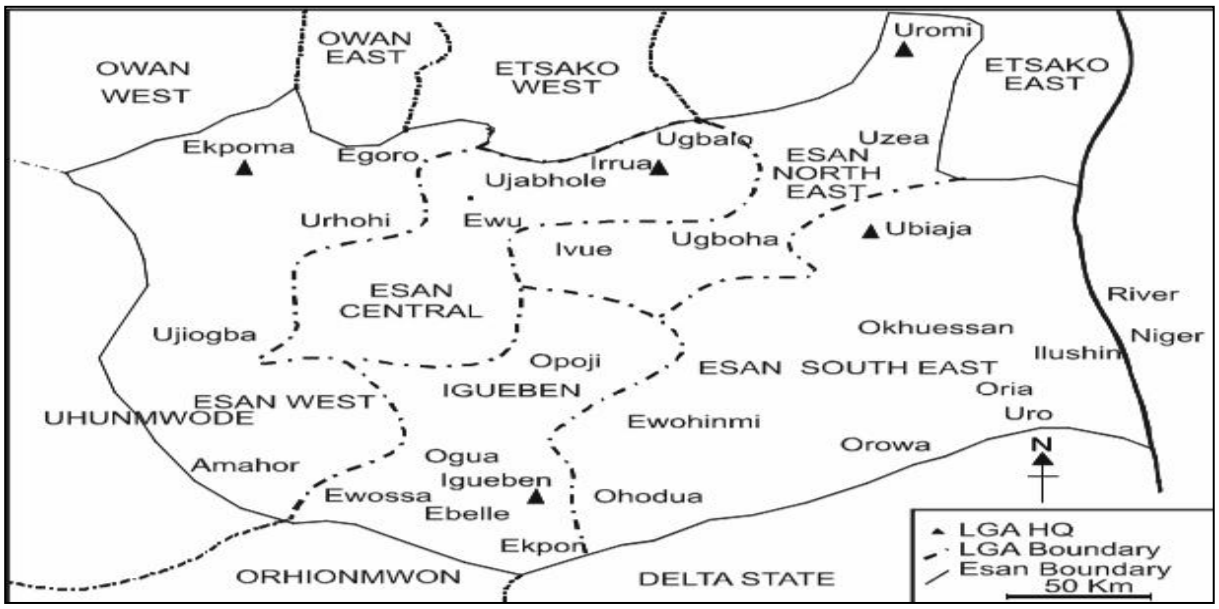

Fig 2.1: Edo state showing central senatorial district. (Source: Samson and Kadiri, 2007)

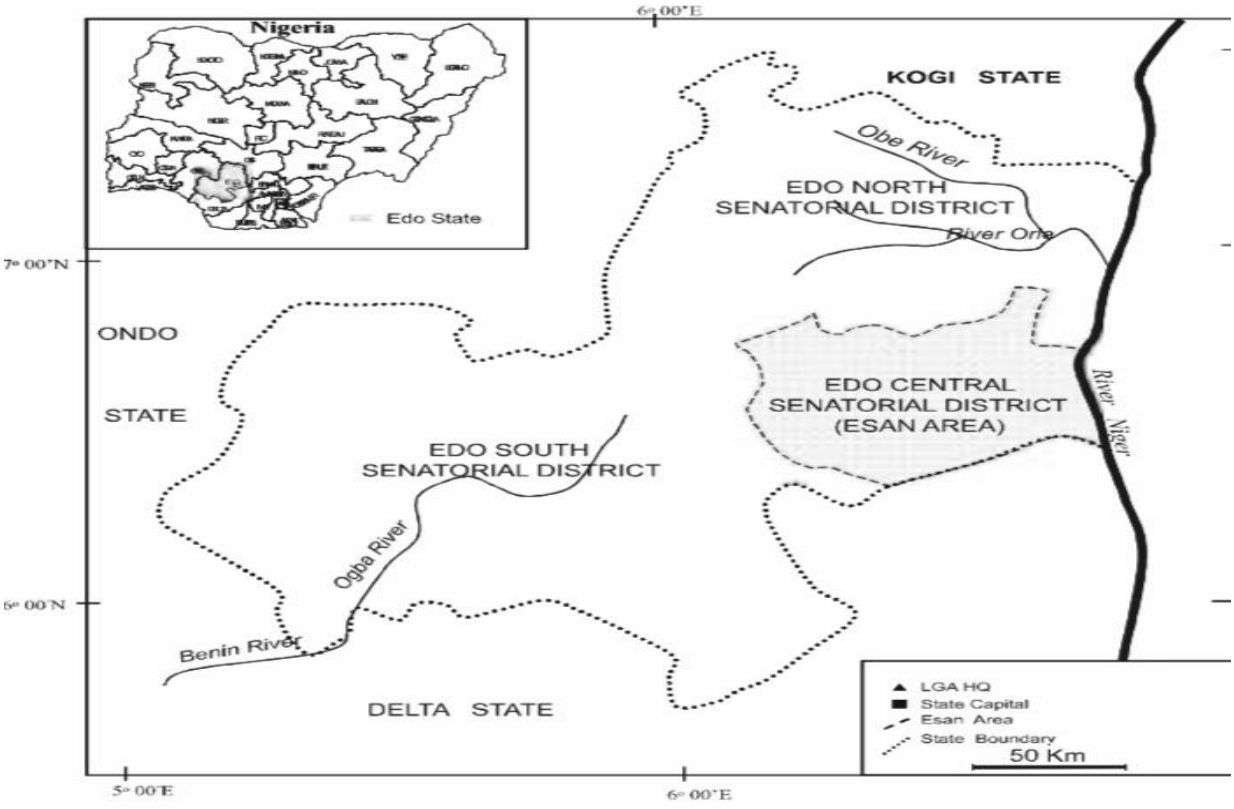

Fig 2.2: Esan region of Edo state (Rice producing Area). (Source: Samson and Kadiri, 2007).

Food crop production in Nigeria faces numerous challenges. In particular, rice cultivation in the study area is hindered by several problems, as outlined in Table 2.2. All respondents identified inadequate financing as the most difficult challenge faced by rice farmers. The next major issues involve pests (such as birds), rodents (like rats and grasscutters), and diseases (including rice blast, smut, narrow brown leaf spot, leaf blight, and root rot). Many farmers reported severe damage to their rice fields caused by birds and grasscutters.

The combined impact of these problems results in low yields per hectare, leading to poor financial returns. This situation is aggravated by competition from cassava cultivation, which offers higher profits. Approximately 92% of the farmers rely on basic tools like cutlasses, hoes, and knives, while the remaining 8% did not list crude implements as a problem. None of the surveyed farmers used modern machinery such as tractors, and no such equipment was

observed during field visits. Similarly, the use of modern inputs likes fertilizers and improved, high-yield rice varieties is uncommon in the area. Farmers complained that fertilizers were too expensive for them to afford.

Improved rice seed varieties were also rare, and where available, the absence of agricultural extension workers made it difficult for farmers to learn proper planting, maintenance, and harvesting techniques. Other social factors affecting rice production include poor transportation, low literacy levels, and an ageing farming population. While roads connecting local government headquarters are relatively good, those linking rural communities to farms and markets are in poor condition. About 90% of the farmers surveyed cited inadequate transportation as a major constraint to food production.

Education also plays a key role in the adoption of new farming technologies. Over half (54%) of the farmers had no formal education, while about 40% had only primary education (Table 2.3). This low educational attainment poses a serious barrier to the dissemination and adoption of modern agricultural practices and innovations.

Table 2.2: Problem of rice production in Central District of Edo State

S. No.	Identified Problems	No. of Respondents	Percentage
1.	Finance(e.g Agric Loans)	1020	100
2.	Pest, diseases and Rodents	1010	99.0
3.	Low Returns	960	94.0
4.	Competition from cassava	950	93.0
5.	Use of crude implements	940	92.0
6.	Lack of modern farm inputs	930	91.0
7.	Transport Problems	910	89.0
8.	Illiteracy	868	85.0
9.	Ageing farming population	781	77.0
10.	Lack of extension worker	776	76.0

(Source: Field Survey, 2003)

Table 2.3: Education Status of respondents.

Education Status	No. of Respondents	Percentage
No formal education	541	53.0
Primary School	110	40.2
Post Primary School	48	4.8
Tertiary Education	21	2.0
Total	1020	100

(Source: Field Survey, 2003)

2.2. Unrefined rice and its health benefits

2.2.1. Unrefined rice

Ekpoma rice is a typical example of unrefined rice. Unrefined rice is celebrated for its rich nutritional profile, boasting higher levels of essential nutrients, dietary fiber, and antioxidants compared to refined white rice. The outer bran layer of unrefined rice contains valuable nutrients such as vitamins (B vitamins, vitamin E), minerals (iron, magnesium, zinc), antioxidants (phytonutrients, polyphenols), and dietary fiber (Rahimi *et al.,* 2019). Unrefined rice is classified as a whole grain because its post-harvest processing involves only the removal of the rice husk, leaving the bran layer attached to the endosperm. It is recognized for its health benefits as it contains higher levels of nutrients and bioactive phytochemicals than refined rice (Munarko *et al.,* 2020; Ukpong *et al.,* 2024; Yan *et al.,* 2020). Meanwhile, the global organic rice market is projected to grow at an annual rate of 8%, driven by consumer preferences for healthier, environmentally friendly, and convenient food choices.

(Bergman and Pandhi, 2023; Hazra *et al.,* 2018). This trend underscores the strong market potential of unrefined organic rice in the future. There are various types of unrefined rice available, but the most commonly found in the market are brown rice and some pigmented rice varieties, such as red and black rice (Pengkumsri *et al.,* 2015). Brown rice is an important source of phytochemicals including phenolic acids, γ-oryzanol and γ-aminobutyric acid [Munarko *et al.,* 2020; Shao *et al.,* 2018], while red rice and black rice, in addition, are rich in anthocyanins and proanthocyanins, respectively, which ensures their greater antioxidant capacity. (Jantasee *et al.,* 2014; Shao *et al.,* 2018).

2.2.2. Health Benefits of Unrefined rice

The consumption of unrefined rice offers a range of health benefits, including better digestive function, improved regulation of blood sugar, enhanced cardiovascular health, and support for weight management. Its rich dietary fiber content aids in maintaining regular bowel movements, preventing constipation, and promoting overall digestive well-being.

Moreover, unrefined rice possesses a lower glycemic index than polished white rice, resulting in a slower and more controlled release of glucose into the bloodstream after eating. This property helps lower the risk of developing insulin resistance, type 2 diabetes, and metabolic syndrome, making unrefined rice a suitable option for individuals aiming to maintain stable blood sugar levels and improve overall metabolic health (Saleem *et al*., 2016; Sanchez-Reinoso *et al*., 2016; Taleei *et al*., 2014).

In addition, unpolished rice contains beneficial antioxidants—such as phytonutrients and polyphenols—that help protect body cells from oxidative stress caused by free radicals. This antioxidant activity contributes to reducing the likelihood of chronic diseases, including cardiovascular conditions, cancer, and neurodegenerative disorders.

Unrefined rice stands as a nutritional powerhouse and culinary delight, offering a myriad of health benefits, culinary versatility, and wholesome goodness. With its rich nutritional profile, robust flavour, and satisfying texture, unrefined rice has earned its place as a cherished staple in diets around the world.

As we strive to nourish our bodies and promote well-being, let us embrace the virtues of unrefined rice and incorporate it into our meals with creativity and joy. Whether enjoyed as a simple side dish or as the center piece of a festive feast, unrefined rice reminds us of the abundance and diversity of nature's bounty, inviting us to savour each grain and celebrate the goodness of Whole Foods. (Wang *et al.,* 2013; Wang *et al.,* 2003).

2.3. Discovery of African Rice

In 1753, Linnaeus classified the genus *Oryza,* recognizing only one cultivated rice species at the time, *O. sativa*, or Asian rice. A century later, in 1855, Steudel identified the African rice species *O. glaberrima* using specimens gathered by French naval officer Edelstan Jardin between 1845 and 1848 along the coast of Portuguese Guinea (now Guinea-Bissau). Jardin had initially labeled the specimens as *O. sativa*. The type specimen is preserved at the National Museum of Natural History in Paris. Later, in 1875, Jardin noted that Steudel's *O. glaberrima* description was based on materials he himself had collected from the Loss Islands, near the Conakry Peninsula (Porteres, 1955).

Even earlier, between 1824 and 1829, French navy pharmacist Leprieur had collected plant samples in Senegal, including rice from Cape Verde near Dakar. The Natural History Museum in Paris houses a herbarium sheet labeled 'Leprieur (1826)' as *O. sativa,* containing two specimens mounted side by side. Porteres later determined that the left specimen was *O. glaberrima* and the right one *O. sativa*, concluding that Leprieur's sheet represented the oldest known specimen of *O. glaberrima*, predating Jardin's by about 20 years. Following the

collections by Leprieur and Jardin, *O. glaberrima* was next collected only in 1899 by Chevalier from regions of upper Senegal–Niger and along the Casamance River (Porteres, 1955).

Based on these findings and the accounts of Porteres and Chevalier, it appears that *O. glaberrima* was not extensively cultivated even during its first recorded collection in the mid-1800s. The long delay in its identification, despite occurring in West Africa's rice-growing regions, supports this view. However, since records indicate that rice cultivation existed in North and East Africa as early as the 1st century BC, it is plausible that the rice observed by early writers like Strabo, al-Bakri, and Ibn Battuta was not *O. glaberrima* but rather *O. sativa* or possibly wild rice species such as *O. barthii* or *O. longistaminata*—most likely the former.

Researchers who have examined the taxonomy of the genus *Oryza* agree on recognizing both African and Asian cultivated rice as distinct species (Chatterjee, 1948). The two can be differentiated primarily by ligule length, panicle structure, and the absence of hairs on the spikelets. Nonetheless, Chevalier and Porteres—who studied *O. glaberrima* extensively—argued that no single characteristic consistently separates the two species, as they exhibit parallel variations in all traits, even within West African populations (Porteres, 1962).

Several features once thought unique to *O. glaberrima*—such as red pericarp, the presence of awns, and fragile grains—are also commonly found in *O. sativa* (Nayar, 1973). Notably, a French research team collecting rice in western India (Konkan and Gujarat) during the late 1980s observed that many *Oryza rufipogon* samples, both perennial and annual, shared significant isozymic and morphological similarities with *O. barthii* and *O. glaberrima* (see Table 2.3).

Archaeological findings lend support to Porteres' (1962) hypothesis that *Oryza glaberrima* was domesticated in the "Inland Niger Delta" (IND) — a region of about 50,000 km² located between the Niger River and its major tributary, the Bani, in southern Mali. This area lies along the southern edge of the Sahel, just below the Sahara Desert. The floodplains of the IND also host extensive populations of two wild rice species, *O. barthii* and *O. longistaminata*, both of which have larger and heavier spikelets than *O. glaberrima*. Among them, *O. barthii* is particularly noted for its good seed production, leading many researchers (Harlan, 1989) to suggest that *O.glaberrima* evolved from this species. However, other scholars, such as Nayar (1973), have proposed that it may have originated from Asian rice.

Traditionally, the indigenous people of the region harvested the grains of both wild species for food, particularly *O. barthii*. Archaeological and historical data suggest that the IND was one of the earliest regions in West Africa to develop settled communities and agriculture. The area is also believed to be the center of domestication for several other crops, including pearl millet, fonio, finger millet, and cowpea.

Linguistic evidence indicates that in parts of West Africa where rice cultivation was introduced relatively late—after contact with European traders—local languages adopted foreign words for rice from Arabic and European sources such as erruz, eruz, arroz, riz, rijst, and rice (Carnay, 2001). In contrast, in regions where rice cultivation predated European contact, native African terms were used instead. For instance, in Senegal and The Gambia—where the Portuguese first arrived in the 15th century—the Mandinka and Wolof words mano and malo (or their variants) are used, while in the IND region, the local term is maaro.

The precise age of African rice cultivation in its secondary centers of diversification, such as along the Gambia River and the Guinea Highlands, remains uncertain. Its spread is often linked to the migrations of the Mande people between the 12th and 16th centuries (Carnay,

2001). The Mande homeland was situated near the upper reaches of the Niger River and its tributaries, from where they are believed to have dispersed rice cultivation across West Africa. During this period, the region experienced increasing aridity, making the IND an important hub for agriculture, fishing, herding, and trans-Saharan trade (MacEachern, 2005). The Mande cultural and agricultural influence remained dominant until the 16th century, when European powers—first the Portuguese, followed by the French and British—rose to prominence. The ensuing 300–400 years of European trade and the slave trade led to the breakdown of African societies in the region, which may have also contributed to the decline of African rice cultivation.

Along the West African coast, Asian rice (*O. sativa*) was believed to have been introduced in two areas: between the Casamance (Senegal) and Cacheu (Guinea-Bissau) rivers, and between Conakry (Guinea) and Buchanan (Liberia) (Porteres, 1962). Porteres suggested that the adoption of Asian rice in these regions indicated prior familiarity with rice farming—likely through *O.glaberrima*—yet no definitive evidence has been found to confirm this.

Table 2.3: Major Rice ecosystems of West Africa

Type	Estimated area (m ha)	Main growing areas	Sowing/planting method	Species planted
Inland deep water	0.5	IND (South Mali), Sokoto valley(North Nigeria)	Broadcasting	*glaberrima*, partly *sativa*
Lowland rainfed	1.8	Throughout, except Sudan region	Broadcasting/transplanting	*sativa,* partly *glaberrima*
Upland rainfed	1.8	Hill slopes of the coastal region	Broadcasting	*glaberrima* and *sativa*
Lowland irrigated	0.6	South Mali, North Nigeria, Niger	Broadcasting/transplanting	*sativa*
Mangrove swamp	0.3	Guinea, Sierra Leone, East Nigeria	Transplanting	*sativa*

Source: (Ndjiondjop *et al.,* 2008)

2.4. PROXIMATE ANALYSIS

This technique involves the separation and quantification of different components such as moisture, ash, crude protein, crude fat, and crude fiber. The information obtained from the proximate analysis can be used to evaluate the nutritional value of a food or feed, to determine its shelf- life, and to assess its suitability for various industrial applications. (Sharma and Gupta,2022)

Key components analyzed in proximate analysis

Proximate composition of the samples were determined using the AOAC methods (AOAC,

1980).

The following is an overview of what proximate analysis entails.

Moisture:

Moisture analysis determines the amount or percentage of water in the sample. “The moisture content of any food is a measure of its water activity and may be used to define its stability and susceptibility to microbial infection. (Davey, 1989). The high moisture content offers the greater activity of water-soluble enzymes and co-enzymes required for the metabolic activities of these food products. (Iheanacho and Ubebani, 2009).

Ash:

Ash analysis determines the amount of inorganic matter in a sample. The ash is the non-gaseous and non- volatile residue that is left behind after the thorough incineration of any matter. The ash is home to minerals. The quantity of mineral content is directly proportional to the content of Ash present in the food materials. (Omotoso, 2005).

Crude protein:

Crude protein analysis determines the total protein content of the sample. Proteins are made up of amino acids. Due to the possibility that the rate of need for these amino acids may exceed the rate of synthesis in the body, arginine, proline, glycine, and glutamine are regarded as conditionally essential nutrients. Compared to beans (78%) and corn (86%), red meat is around 94% digestible.

Fat:

The crude fat analysis measures the number of lipids in the sample. "Accumulation of fats can cause arteriosclerosis and aging"(Shaheen, 2013). The primary function of Dietary fats is to increase the palatability of food by absorbing and retaining flavors. High fats consumption in the diet causes atherosclerosis, cancer, and aging"(Antia, 2006).

Fiber:

Fibers are the indigestible part of the diet, which is also called bulk or roughage. Fibers support good health and are known to lower cholesterol levels. Heart disease, rectum and colon cancer, varicose veins, diabetes, phlebitis, appendicitis, obesity, and even constipation have all been linked to low-fiber diets. (Lajide *et al.,* 2008).

Carbohydrate:

The total amount of carbohydrates in a sample can be determined using carbohydrate analysis. It consists of a number of different components, such as sugars, starches, dietary fiber, and other carbohydrates. Depending on the particular component of interest, there are many techniques for carbohydrate analysis, including enzymatic assays, high-performance liquid chromatography (HPLC), and gravimetric approaches. (BeMiller, 2017).

2.5. Methods and Techniques for Proximate Analysis

2.5.1. Sample collection and preparation

A total of one hundred samples consisting of twenty five samples each of four varieties of white unpolished Nigerian local rice *Oryza glaberrima* (Ofada rice, Abakaliki rice, Ekpoma rice, and Igbimo rice) were purchased from Ofada in Ogun State, Nigeria and conveyed to the laboratory(Obadina *et al.,* 2017). The rice samples were checked visually for stones, dirts and other extraneous objects which were removed manually, sorted, milled and sieved to obtain rice flour. Flour samples produced from rice varieties were placed in cellophane bag until the samples were subjected to analyses within 48hrs at ambient temperature.

2.5.2. Determination of moisture content

The determination of moisture content is commonly carried out through two main processes;

Karl Fischer titration and drying methods such as oven drying.

Oven Drying

The moisture content of samples were measured as described by AOAC method (AOAC 1980). Crucibles were thoroughly washed and dried in an oven at 100°C for 30mins and allow to cook inside dessicators. After cooling, they were weighed as W_1. Then, 2.0g of the finely ground rice samples were placed inside the oven and dried at 100°C for 4 hours, cooled and weighed at the same temperature for 30 minutes until constant were obtained as W_3. Then, the moisture content of the rice sample was calculated.

Moisture (%) = $(W_2-W_3)/(W_2-W_1) \times 100$

Where, W_1= Initial weight of empty crucible,

W_2 = Weight of crucible + sample before drying

W_3 = Final weight of crucible + sample after drying

(Aminu *et al.,* 2021)

Fig 2.3: Automated Karl Fischer volumetric titration unit. (Source: Mauer and Bradley Jr, 2017)

2.5.3. Rice Flour

Rice flour (also rice powder) is a form of flour made from finely milled rice. Rice flour may be made from either white rice, brown rice or glutinous rice. To make the flour, the husk of rice or paddy is removed and raw rice is obtained, which is then ground to flour. Rice flour is used to produce various food products such as traditional Asian foods, baked products, noodles, extruded products or as additive of other ingredients. The qualities of these products

depended on the physicochemical properties of rice flour (Jangchud *et al.,* 2004). Previous studies revealed that rice flour from different varieties were different in the amylose, amylopectin, starch, protein, lipid and ash contents (Zhou *et al.,* 2002). The difference in chemical composition of rice flour affected the functional, thermal and pasting properties (Derycke *et al.,* 2005). Starch, as main composition of rice flour, is composed of two glucose polymers: amylose and amylopectin. (Champagne,1996).

Both amylose and amylopectin affected the functional, pasting, gelatinization and retrogradation properties of rice flour. (Singh *et al.,* 2000). Amylose acts as an inhibitor of swelling but it can create a gel network and and sets the structure of flour gel in short-term (less than 1 day) changes, while amylopectin is responsible for the longer term structural changes. (Bhattacharya *et al.,* 1999). Besides amylose and amylopectin, protein and lipids, which are minor components of rice flour, also affects the properties of rice flour such as restricting the expansion of starch granules during gelatinization or retarding amylopectin retrogradation. (Tester and Morrison, 1990).

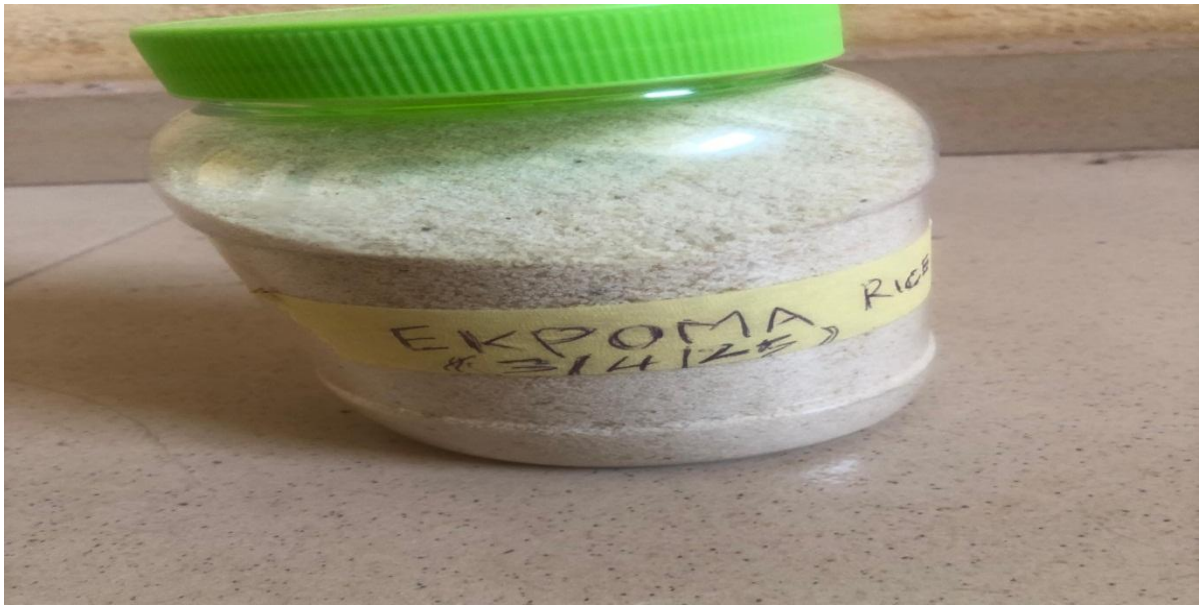

Fig 2.4: Packed and unpacked Ekpoma rice flour (Photo Credit: Okunzuwa, S. 2025)

CHAPTER THREE

MATERIALS AND METHODS

3.0. COLLECTION OF SAMPLE

Ekpoma rice was purchased at New Benin market, Benin City, Edo state, Nigeria. It was screened and blended into powder flour.

3.1. MATERIALS

3.1.1. Apparatus

1. Beakers
2. Volumetric flask
3. Test tubes
4. Moisture can (silica dish or crucible)
5. Hot air drying oven
6. Conical flask
7. Measuring cylinder
8. Burette
9. Test tube rack
10. Poplin cloth
11. Spatula
12. Extraction boiling flask,250-ml capacity

13. Dry porous thimble

14. Digestion tubes

15. Shaped No,4 filter paper

16. Cotton wool

3.1.2. Equipment

1. Muffle furnace

2. Hot air drying oven

3. Dessicator

4. Spectrophotometer

5. Soxhlet extractor

6. Heater

7. PG instrument AA500F(AAS)

8. Analytical weighing balance

9. Mechanical shaker

10. Buchner filtration unit

11. Water bath or mantle heater

3.1.3. Reagents

1. Concentrated Sulphuric acid

2. Sodium hydroxide

3. Concentrated Nitric acid(HNO_3)

4. Petroleum ether (40-60℃ boiling point)

5. Ammonium chloride

6. Sodium acetate

7. Acetic Acid, 99.5% purity.

8. Sodium hypochlorite

9. Alkaline sodium phenate solution

10. Potassium cyanide (10% solution)

11. standard Calcium solution.

12. Neutral amminum acetate

13. Ammonium molybdate

14. Ascorbic acid

15. Antimony potassium tartrate

16. Buffer solution (pH 10): Dissolve

17.5g of A.R NH_4Cl in 142ml Concentrated NH_4OH and dilute to

250ml with distilled water.

18. Concentrated Nitric Acid (HNO_3, trace metal grade)

19. Concentrated Perchloric Acid ($HClO_4$)

20. Certified AAS standards (1000 mg/L) of Mg, Na, K, Fe, Zn, Cu, Mn

21. De ionized or distilled water

22. Hydroxylamine hydro chloride (10% solution):Dissolve 10g of hydroxylamine hydrochloride

in distilled water and make up to 100ml in a volumetric flask

23. Indicator(Erichrome Black T): Dissolve 0.5g of the dye Erichrome Black T and up to 100ml with 95% ethanol

24. Neutral amminum acetate: Ammonium acetate solution,inPH 7.0-Add 58ml of glacial acetic

acid to about 600ml of distilled water in a 2 litre beaker.Add 70ml conc.Ammonium solution specific quantity (0.90).The ammonium solution is best added under a fume hood through a long stemmed glass funnel so that it is introduced into the bottom of the acid solution.Cool this solution and adjust to pH 7.0 with acetic acid or ammonia solution using a pH Meter.Transfer the solution into a 1 litre volumetric flask and dilute to volume.

25. Phosphoric Acid,85%

26. Potassium cyanide (10% solution): Dissolve 10g of KCN in distilled water and make up to

100ml in volumetric flask

27. Potassium hydrogen phosphate (KH_2PO_4)

28. Potassium Peroxide (KIO_4) Hydroxylamine hydrochloride (10% solution): Dissolve 10gof

hydroxylamine hydrochloride in distilled water and make up to 100ml in a volumetric flask

29.Selenium catalyst tablet

30. Sodium acetate potassium hydrogen phosphate (KH_2PO_4)

31.Sodium potassium tartrate

32. Standard EDTA titrant,0.004M:Weigh 1.489g of dry AR grade disodium ethylenediamine tetra acetate dihydrate (molecular weight of 372.24), dissolve in distilled water and dilute to 1000ml.Check the titre by standardising against standard Calcium solution

3.2. SAMPLE PREPARATION

3.2.1. Preparation of rice flour

The rice sample (Ekpoma rice) was milled using a rice grinding machine. The rice flour was packaged in an airtight container until needed.

3.3. DETERMINATION OF MOISTURE CONTENT

Procedure

1. Weigh the moisture can empty,(W_0).

2. Add about 2g material and weigh the moisture can again with the material (W_1).

3. Dry in the hot air drying oven at 105-110°C for 24 hours.

4. Cool in a desiccator.

5. Weigh the can with the dry sample (W_2).

6. Return the dried sample to the oven for further 24 hours to make sure that the drying is complete.

7. Weigh again, the weight of W_2 , should be constant now otherwise dry again in the oven until

constant weigh is obtained.

CALCULATION

$$\% \text{ Moisture content} = \frac{W_1 - W_2}{W_1 - W_0} \times 100$$

Where;

W_1 = Weight of the moisture can with the material

W_2= Weight of the can with Dry sample

W_0= Weight of the moisture can empty

3.4. DETERMINATION OF ASH AND SILICA CONTENT, AOAC METHOD

Procedure

1. Weigh the crucible or dish empty = (W_0)

2. Add sample and weigh crucible plus sample = (W_1)

3. Ash in the muftle furnace 500-600°for 3 hours.

4. Cool the sample in a desiccator

5. Weigh the crucible and dry sample (W_2).

CALCULATION

$$\% \text{ Ash} = \frac{W_1 - W_2}{W_1 - W_0} \times 100$$

Where;

W_1 = Weight of crucible plus sample

W_2 = Weight of crucible and Dry sample

W_0 = Weight of crucible

B. Silica Determination

1. Moisten the ash above with conc. HCL

2. Heat on water-both to dryness

3. Add 30 ml of 1 percent HCL

4. Filter using folded filter paper, No.4.

5. Wash 3 times with hot distilled water

6. Remove the filter paper with the content carefully, fold it and put back into the crucible.

7. Char it and ash in the Muffle furnace at 500-600 °C for 3 hours.

8. Cool in the desiccator

9. Weigh the crucible with the dry sample (W_3).

3.5. DETERMINATION OF CRUDE FAT

Procedure

1. Dry 250-ml extraction flask in the oven at 105-110°C.

2. After allowing it to cool in the desiccator weigh the extraction flask empty

3. Weigh accurately 0.5-2 g of the ground sample into the a labeled porous thimble

4. Cover the porous thimbles mouth with clean white cotton wool.

5. Add about 200 ml of petroleum either into the dry 250-ml extraction flask.

6. Place the cover porous thimble into the condenser and assemble the apparatus.

7. Extract for about 5-6 hours

8. Remove the porous thimble with care and collect the petroleum either in the top container (tube) for re-use.

9. Remove the extraction flask from the water bath when it is almost free of petroleum either.

10. Ovens dry the extraction flask containing the oil or fat at 105-110 °C for one hour.

11.Cool in the desiccator and take the weight after cooling.

CALCULATION

Weight of grounded sample = W_1

Weight of empty extraction flask = W_2

Weight of empty extraction flask+Oil = W_3

Weight of ether (fat or oil) = $W_3 - W_2$

% Fat = $W_3 - W_2 / W_1 \times 100$

3.6. DETERMINATION OF CRUDE FIBRE

Procedure

1. Weigh 0.50-2.00g of the ground sample into a 1-litre conical flask(W_0)

2. Add 200 ml of boiling 1.25% H_2SO_4 and boil gently for 30 minutes using cooling fingers to maintain a constant volume.

3. Filter through muslin cloth of poplin material stretched over 9cm Buchner funnel.

4. Rinse well with hot distilled water.

5. Scrape the material back into a flask with a spatula.

6. Add 20C-ml of boiling 1.25% NaOH and allow boiling gently for 30 minutes using fingers to maintain a constant volume.

7. Filter through poplin cloth.

8. Wash residue thoroughly with hot distilled water.

9. Rinse once with 10% HCI and twice with industrial methylated spirit, acetone or ethanol.

10. Rinse finally three time with petroleum other (BP 40-60°C)

11. Allow to drain dry and then scrap the residue into a crucible or silica dish.

12. Dry overnight at 105°C in the oven.

13. Cool in a desiccator

14. Weigh the sample,(W_1).

15. Ash at 550° C for 90 minutes in a muffle furnace.

16. Cool in a desiccator and weigh again (W_2).

CALCULATION

$$\% \text{ Crude fibre} = \frac{W_1 - W_2}{W_0} \times 100$$

3. 7. DETERMINATION OF CRUDE PROTEIN USING AOAC METHOD

Procedure for Digestion for Nitrogen

1. Grind samples to pass a 40-mesh screen.

2. Weigh duplicate samples containing about 1mg N (25 to 50mg) on a weighing boat, transfer to digestion tube, Add 2ml of distilled water and let it stand for 30 minutes.

3. Add a tablet of selenium catalyst and 5ml of conc.H_2SO_4

4. Heat cautiously in a fume hood until frothing stops.

5. After digestion is cleared (about half an hour), continue boiling for half an hour longer.

6. Allow to cool.

7. Add slowly with swirling, 10ml of distilled water, continue swirling until undissolved

materials are in suspension.

8. Filter through Whatman filter paper NO. 42, make up to mark 100ml volumetric flask. Filtrate is ready for colorimetric analysis.

PROCEDURE

1. Pipette 10ml of filtrate into a 25 ml volumetric flask

2. Add 6ml of potassium sodium tartrate.

3. Add 2ml of alkaline sodium phenate solution.

4. Add 2ml of sodium hypochlorite solution.

5. Make up to the volume with distilled water and mix the content thoroughly.

6. Read the absorbance values of the solution at 630 on UV/Visible Spectrophotometer.

CALCULATION

Making use of the Aurora Quant software in running the samples;

Conc. N(mg/kg) = IR ×SR×CR×ER

Vol. of water in (L)

Where: IR = Instrument Reading (Abs)

SR = Slope Reciprocal

CR = Colour Ratio (colour vol./ Vol of Aliquot)

ER = Extraction Ratio (Final Vol/ Wt. of Sample Digested)

Convert mg/l or mg/kg to percentage.

3.8. DETERMINATION OF CARBOHYDRATE (NITROGEN FREE EXTRACTIVE)

The nitrogen free extractive (N.F.E.) REFERRED TO as soluble carbohydrate is not determined directly but obtained as a difference between crude protein and the sum of ash, protein, crude fat and crude fibre.

N.F.E = 100 - (%Ash+% crude fibre+% crude fat+ %crude protein+%moisture)

N.F,E. does not refer to any particular compound or group of substances but consist of all starches and sugars, some hemicellulose, and varying proportion of lignin. The name, soluble carbohydrate given to the fraction is therefore a misnomer.

3. 9. DETERMINATION OF METALS USING NITRIC-PERCHLORIC ACID DIGESTION

3.9.1. Procedure for (Zn, Fe, Mn, Mg, Ca, Na, K)

PROCEDURE

SAMPLE PROCESSING

• Place samples in a glass petri dish and dry them in the oven at 105^{O}C

• After 24hrs of drying, any lump present should be broken up with a clean glass rod in order to expose the inside for drying.

• After drying, the sample should be grinded to fine powder using mortar and pestle.

3.9.2. DIGESTION PROCEDURE

1. Weigh 1g of grinded sample into a conical flask

2. Add 10ml of the Nitric – Perchloric acid mixture, let soak overnight

3. Insert a small glass funnel to act as a reflux condenser and heat for 1hrs at 150^{O}C

4. Gradually raise the temperature to 235^{O}C. When dense white fume occur, continue the heating for another 2hrs.

5. Remove from the block, cool to about 100^{O}C and add 1ml of 1:1HCl, heat to white fumes and then until a colourless solution is obtained.

6. Fitter the solution into 100ml vol. flask and rinse 5 times with water each time adding the washing to the flask and make up volume.

7. Prepare blank samples using the same procedure without any sample.

8. Analyse the filtrates for heavy metals using AAS

3.10. DETERMINATION OF CALCIUM AND MAGNESIUM USING EDTA (VERSENATE) TITRATION

3.10.1 Extraction method:

1. Weigh 10g of air dried soil sample in 250 polythene bottle

Add 100ml of neutral ammonium acetate.

2. Shake for 45-60 minutes in a mechanical shaker.

3. Filter through No.42 whatman filter paper.

4. Filtrate is ready for analysis for Ca, Mg, Na and amp;K

PROCEDURE

1. 1 25ml of filtrate sample in 250ml conical flask.

2. Add 5ml of KOH and 0.5ml each of KCN and Hydroxylamine hydrochloride solutions.

3. Add 2 drops of Calred indicator solution.

4. Titrate over a white surface with standard 0.004M EDTA titrant slowly with continuous stirring until the reddish tinge disappears from the solution, adding the last few drops at 3-5 seconds intervals. The colour of the solution at the end point is blue under normal conditions.

CALCULATION

IF V1 is the volume of Versenate used in titration

Ca^{2+} (in meq/l) = N x V_1 X 1000/25

Where

N = Normality of versenate

V_1= Volume of versenate

(1ml of IM EDTA = 40.08 mg Ca per aliquot

1ml of 0.004M EDTA = 0.16032 mg Ca per 25ml aliquot

T titre of 0.004M EDTA=0.16032T mg Ca per 25ml aliquot= 0.16032 T x 1000/25 x extraction ratio mg/kg as Ca)

Where T is the titre value

3.11. Calcium And Magnesium

1. 25ml of filtrate sample in 250ml conical flask.

2. Add 5ml of buffer solution and 0.5ml each of KCN and Hydroxylamine hydrochloride solutions.

3. Add 2 drops of Eriochrome Black T indicator solution.

4. Titrate over a white surface with standard 0.004M EDTA titrant slowly with continuous stirring until the reddish tinge disappears from the solution, adding the last few drops at

3-5 seconds intervals. The colour of the solution at the end point is blue under normal conditions.

CALCULATION

If V_2 is the volume of Versenate used in the titration

then

$Ca^{2+} + Mg^{2+}$ (meq)=N x V_2 1000/25

The amount of Mg^{2+} = is obtained by subtracting the value of calcium from the value obtained

for ($Ca^{2+} = Mg^{2+}$)

3.12. DETERMINATION OF PHOSPHORUS

PROCEDURE

1. Pipette 5ml of sample into a 25ml volumetric flask. Add distilled water to bring the

volume to approximately 15ml.

2. Add 8ml of reagent B to samples and set of working standard solutions in the volumetric

flask. Make up to volume with distilled water and mix the content thoroughly.

3. Determine the absorbance values the colour at 660nm with 30 minutes on

4. Unicam 5625 Spectrometer. Shake the content in a flue flask before encasement.

CALCULATION

With Aurora Quanta Software attached:

Conc.P mg/l Vo1.of watcr =(1

Where DF=Dilution factor

AC=Conc.(mg/I)

EV=Final volume (1).

3.13. Procedure for the Determination of Mg, Na, K, Fe, Zn, Cu, Mn in Rice Flour Using AAS

Sample Preparation and Digestion Weighing

• Accurately weigh 0.5 g of rice flour sample into a clean digestion flask or tube.

3.13.1 Acid Digestion

1. Add 10 mL of a 3:1 mixture of HNO_3:$HClO_4$.

2. Let the mixture stand overnight at room temperature (optional but helps pre-digest).

3. Heat the flask on a hot plate at 150–180°C in a fume hood:

- Continue until dense white fumes appear (indicating perchloric acid action).
- The digest should become clear and colorless.

4. Allow to cool.

5. Filter the digest using Whatman No. 42 filter paper if any residue is present.

6. Transfer the filtrate to a 50 mL or 100 mL volumetric flask and make up to the mark with deionized water.

3.13.2. Measurement Procedure

1. Warm up AAS and allow lamp stabilization.

2. Calibrate using standard solutions.

3. Measure the absorbance of the blank, standards, and sample digests.

4. Construct calibration curves (absorbance vs. concentration).

5. Determine sample concentrations by interpolation from the curve.

CALCULATION

Use the calibration curve for each element to determine the concentration in the sample digest.

Then:

Element concentration (mg/kg) = C×V/W

Where:

• C = concentration from AAS (mg/L)

• V = final volume of digest (ml)

• W = sample weight digested (g)

3.14. AMINO ACID

3.14.1. Defatting Sample:

The sample was defatted using chloroform/methanol mixture of ratio 2:1. About 5g of the

sample was put in an extraction thimble(or filter paper) and extracted for 15 hours in a soxhlet

extraction apparatus (AOAC, 2006).

3.14.2. Nitrogen Determination:

A small amount (150mg) of ground sample was weighed, wrapped in whatman filter paper

(No.1) and put in the Kjeldal digestion flask. Concentrated sulphuric acid (10ml) was added.

Catalyst mixture (0.5g) containing sodium sulphate ($Na_2 SO_4$), copper sulphate ($CuSO_4$) and

selenium oxide (SeO_2) in the ratio of 10:5:1 was added into the flask to facilitate digestion. Six pieces of anti-bumping granules were added.

The flask was then put in the Kjeldhal digestion apparatus for 3 hours until the liquid turned light green. The digested sample was cooled and diluted with distilled water to 100ml in standard volumetric flask. Aliquot (10m1) of the diluted solution with 10ml of 45% sodium hydroxide was put into the Markham distillation apparatus and distilled into 10ml of 2% boric acid containing 4 drops of bromocresol green/methyl red indicator until about 70ml of distillate was collected.

The distillate was then titrated with standardized 0.01N hydrochloric acid to grey colored end point.

CALCULATION

Percentage Nitrogen =(a-b) x 0.01 x 14 x V x 100

W x C

Where:

a. =Titre value of the digested sample

b. =Titre value of blank sample

v.=Volume after dilution (100ml)

W.=Weight of dried sample (mg)

C.=Aliquot of the sample used

14.=Nitrogen constant in mg.

CHAPTER FOUR

RESULTS

Proximate, mineral, and amino-acid composition analysis was carried out on Ekpoma rice sample from a period of 0 to 3 months. The results obtained from each month analysis is tabulated below:

TABLE 4.1: Results for the proximate analysis of Ekpoma rice (Month 0)

Parameters (%)	A	B	MEAN
Moisture	9.58	9.61	9.60±0.02
Protein	5.84	5.93	5.89±0.05
Fat	1.10	0.90	1.00±0.10
Ash	0.45	0.50	0.48±0.03
Crude fibre	0.47	0.46	0.47±0.01
Carbohydrate	82.56	82.60	82.52±0.06
Nitrogen	933.94	948.07	941.07±7.13

TABLE 4.2: Results for the proximate analysis of Ekpoma rice (Month 1)

Parmeters (%)	A	B	MEAN
Moisture	11.05	10.95	11.00±0.05
Protein	5.83	5.88	5.86±0.03
Fat	0.90	0.90	0.90±0.00
Ash	0.44	0.46	0.67±0.22
Crude fibre	0.18	0.20	0.19±0.01
Carbohydrate	81.60	82.35	81.98±0.38
Nitrogen	932.80	940.80	936.80±4.00

TABLE 4.3: Results for the proximate analysis of Ekpoma rice (Month 2)

Parmeters (%)	A	B	MEAN
Moisture	10.75	10.65	10.70±0.05
Protein	5.53	5.58	5.56±0.03
Fat	0.80	0.80	0.80±0.00
Ash	0.32	0.34	0.33±0.01
Crude fibre	0.08	0.10	0.09±0.01
Carbohydrate	81.41	82.20	81.81±0.35
Nitrogen	932.50	938.50	935.50±3.00

TABLE 4.4: Results for the proximate analysis of Ekpoma rice (Month 3)

Parmeters (%)	A	B	MEAN
Moisture	10.72	10.60	10.66±0.06
Protein	5.50	5.55	5.53±0.03
Fat	0.75	0.75	0.75±0.00
Ash	0.30	0.32	0.31±0.01
Crude fibre	0.07	0.09	0.08±0.01
Carbohydrate	81.30	82.00	81.65±0.35
Nitrogen	932.00	937.50	934.75±2.75

TABLE 4.5: Results for the mineral analysis of Ekpoma rice (Month 0)

Parameters (mg/100g)	A	B	MEAN
Calcium	51.30	51.30	51.30±0.00
Magnesium	15.58	15.56	15.57±0.01
Sodium	8.84	8.86	8.85±0.01
Potassium	116.1	115.99	116.05±0.06
Manganese	0.60	0.61	0.61±0.0071
Zinc	2.21	2.23	2.22±0.01
Iron	8.08	8.12	8.10±0.02
Phosphorus	106.53	108.07	107.30±0.77

TABLE 4.6: Results for the mineral analysis of Ekpoma rice (Month 1)

Parameters (mg/100g)	A	B	MEAN
Calcium	50.94	51.05	50.995±0.06
Magnesium	15.35	14.98	15.17±0.19
Sodium	8.85	8.76	8.81±0.05
Potassium	114.80	115.20	115.00±0.20
Manganese	0.47	0.54	0.51±0.041
Zinc	2.20	2.18	2.19±0.01
Iron	0.81	0.76	0.79±0.025
Phosphorus	107.40	106.80	107.10±0.30

TABLE 4.7: Results for the mineral analysis of Ekpoma rice (Month 2)

Parameters (mg/100g)	A	B	MEAN
Calcium	49.82	50.05	49.94±0.12
Magnesium	14.90	13.90	14.40±0.50
Sodium	7.95	7.80	7.88±0.08
Potassium	113.50	114.20	113.85±0.35
Manganese	0.30	0.42	0.36±0.06
Zinc	1.80	1.73	1.77±0.04
Iron	0.70	0.65	0.68±0.025
Phosphorus	106.50	105.20	105.85±0.65

TABLE 4.8: Results for the mineral analysis of Ekpoma rice (Month 3)

Parameters (mg/100g)	A	B	MEAN
Calcium	49.75	50.00	49.88±0.13
Magnesium	14.80	13.70	14.25±0.55
Sodium	7.82	7.75	7.79±0.04
Potassium	113.20	114.00	113.60±0.40
Manganese	0.30	0.40	0.35±0.05
Zinc	1.75	1.70	1.73±0.03
Iron	0.65	0.60	0.63±0.03
Phosphorus	106.20	105.10	105.65±0.55

TABLE 4.9: Results for the amino-acid analysis of Ekpoma rice (Month 0)

Amino-acid	A	B	MEAN
Leucine	6.10	6.05	6.08±0.025
Lysine	4.82	4.78	4.80±0.02
Isoleucine	3.57	3.54	3.56±0.02
Phenylalanine	3.72	3.76	3.74±0.02
Norleucine	INTERNAL STANDARD		
Tryptophan	3.36	3.34	3.35±0.01
Valine	3.54	3.52	3.53±0.01
Methionine	2.56	2.50	2.53±0.03
Proline	2.33	2.35	2.34±0.01
Arginine	5.42	5.36	5.39±0.03
Tyrosine	3.44	3.52	3.48±0.04
Histidine	2.20	2.14	2.17±0.03
Cystine	1.21	1.13	1.17±0.04
Alanine	3.34	3.38	3.36±0.02
Glutamic acid	10.52	10.51	10.52±0.007
Glycine	3.89	3.80	3.85±0.05
Threonine	3.11	3.02	3.07±0.05
Serine	3.02	3.07	3.05±0.03
Aspartic acid	7.19	7.30	7.25±0.06

TABLE 4.10: Results for the amino-acid analysis of Ekpoma rice (Month 1)

Amino-acid	A	B	MEAN
Leucine	6.16	6.11	6.14±0.025
Lysine	4.82	4.81	4.82±0.007
Isoleucine	3.57	3.50	3.54±0.04
Phenylalanine	3.72	3.70	3.71±0.01
Norleucine	INTERNAL	STANDARD	
Tryptophan	3.41	3.31	3.36±0.05
Valine	3.57	3.50	3.54±0.04
Methionine	2.54	3.31	2.93±0.39
Proline	2.33	2.34	2.34±0.007
Arginine	5.42	5.42	5.42±0.00
Tyrosine	3.44	3.48	3.46±0.02
Histidine	2.24	2.18	2.21±0.03
Cystine	1.21	1.17	1.19±0.02
Alanine	3.34	3.36	3.35±0.01
Glutamic acid	10.52	10.59	10.55±0.04
Glycine	3.87	3.83	3.85±0.02
Threonine	3.14	3.08	3.11±0.03
Serine	3.02	3.09	3.06±0.04
Aspartic acid	7.19	7.33	7.26±0.07

TABLE 4.11: Results for the amino-acid analysis of Ekpoma rice (Month 2)

Amino-acid	A	B	MEAN
Leucine	6.14	6.10	6.12±0.02
Lysine	4.81	4.80	4.81±0.007
Isoleucine	3.56	3.48	3.52±0.04
Phenylalanine	3.72	3.69	3.71±0.02
Norleucine	INTERNAL	STANDARD	
Tryptophan	3.40	3.30	3.35±0.05
Valine	3.54	3.47	3.51±0.04
Methionine	2.50	3.30	2.90±0.4
Proline	2.30	2.32	2.31±0.01
Arginine	5.40	5.40	5.40±0.00
Tyrosine	3.40	3.45	3.43±0.03
Histidine	2.20	2.16	2.18±0.02
Cystine	1.20	1.15	1.18±0.03
Alanine	3.30	3.34	3.32±0.02
Glutamic acid	10.50	10.57	10.54±0.04
Glycine	3.85	3.80	3.83±0.03
Threonine	3.12	3.06	3.09±0.03
Serine	3.00	3.05	3.03±0.03
Aspartic acid	7.17	7.30	7.24±0.07

TABLE 4.12: Results for the amino-acid analysis of Ekpoma rice (Month 3)

Amino-acid	A	B	MEAN
Leucine	6.12	6.08	6.10±0.02
Lysine	4.80	4.79	4.80±0.007
Isoleucine	3.54	3.46	3.50±0.04
Phenylalanine	3.70	3.67	3.69±0.016
Norleucine	INTERNAL	STANDARD	
Tryptophan	3.38	3.29	3.34±0.05
Valine	3.52	3.44	3.48±0.04
Methionine	2.48	3.25	2.87±0.39
Proline	2.25	2.30	2.28±0.025
Arginine	5.38	5.38	5.38±0.00
Tyrosine	3.38	3.44	3.41±0.03
Histidine	2.15	2.14	2.15±0.007
Cystine	1.18	1.13	1.16±0.025
Alanine	3.25	3.34	3.30±0.045
Glutamic acid	10.45	10.55	10.50±0.05
Glycine	3.82	3.75	3.79±0.035
Threonine	3.10	3.04	3.07±0.03
Serine	2.28	3.02	2.65±0.37
Aspartic acid	7.14	7.28	7.21±0.07

AVERAGE MEAN VALUE ON THE CHARACTERIZATION OF EKPOMA RICE FOR A PERIOD OF 0 TO 3 MONTHS

TABLE 4.13: PROXIMATE ANALYSIS

PARAMETERS (%)	MONTH 0	MONTH 1	MONTH 2	MONTH 3	p-value
Moisture	9.60±0.02	11.00±0.05	10.70±0.05	10.66±0.06	< 0.001*
Protein	5.89±0.05	5.86±0.03	5.56±0.03	5.53±0.03	< 0.001*
Fat	1.00±0.10	0.9±0.00	0.8±0.00	0.75±0.00	< 0.001*
Ash	0.48±0.03	0.67±0.22	0.33±0.01	0.31±0.01	0.052
Crude fibre	0.47±0.01	0.19±0.01	0.09±0.01	0.08±0.01	< 0.001*
Carbohydrate	82.52±0.06	81.98±0.38	81.81±0.40	81.65±0.35	0.089
Nitrogen	941.07±7.13	936.80±4.00	935.50± 3.00	934.75±2.75	0.342

Interpretation: A general decreasing trend was observed for most parameters over the storage period. The changes in Moisture, Protein, Fat, and Crude fibre were statistically significant ($p < 0.05$), while the changes in Ash, Carbohydrate, and Nitrogen were not.

TABLE 4.14: MINERAL ANALYSIS

PARAMETERS (mg/100g)	MONTH 0	MONTH 1	MONTH 2	MONTH 3	p-value
Calcium	51.30±0.00	50.99±0.06	49.94±0.12	49.88±0.13	< 0.001*
Magnesium	15.57±0.01	15.17±0.19	14.40±0.50	14.25±0.55	< 0.001*
Sodium	8.85±0.01	8.81±0.05	7.88±0.08	7.79±0.04	< 0.001*
Potassium	116.05±0.06	115.00±0.20	113.85±0.35	113.6±0.40	< 0.001*
Manganese	0.61±0.0071	0.51±0.041	0.36±0.06	0.35±0.05	< 0.001*
Zinc	2.22±0.01	2.19±0.01	1.77±0.04	1.73±0.025	< 0.001*
Iron	8.10±0.02	0.79±0.025	0.68±0.025	0.63±0.025	< 0.001*
Phosphorus	107.3±0.77	107.1±0.30	105.85±0.65	105.65±0.55	< 0.001*

Interpretation: A significant decreasing trend in mineral content was observed from Day 0 to Month 3 across all minerals measured. The differences were statistically significant for every parameter ($p < 0.05$).

TABLE 4.15: AMINO-ACID ANALYSIS

AMINO-ACID	MONTH 0	MONTH 1	MONTH 2	MONTH 3	p-value
Leucine	6.08±0.025	6.14±0.025	6.12±0.02	6.10±0.02	0.074
Lysine	4.80±0.02	4.82±0.007	4.81±0.007	4.80±0.007	0.445
Isoleucine	3.56±0.02	3.54±0.04	3.52±0.04	3.50±0.04	0.432
Phenylalanine	3.74±0.02	3.71±0.01	3.71±0.02	3.69±0.016	0.051
Norleucine	INTERNAL	STANDARD			-
Tryptophan	3.35±0.01	3.36±0.05	3.35±0.05	3.34±0.05	0.991
Valine	3.53±0.01	3.54±0.04	3.51±0.04	3.48±0.04	0.432
Methionine	2.53±0.03	2.93±0.39	2.90±0.40	2.87±0.39	0.765
Proline	2.34±0.01	2.34±0.007	2.31±0.01	2.28±0.025	0.052
Arginine	5.39±0.03	5.42±0.00	5.40±0.00	5.38±0.00	0.445
Tyrosine	3.48±0.04	3.46±0.02	3.43±0.03	3.41±0.03	0.052
Histidine	2.17±0.03	2.21±0.03	2.18±0.02	2.15±0.007	0.432
Cystine	1.17±0.04	1.19±0.02	1.18±0.03	1.16±0.025	0.765
Alanine	3.36±0.02	3.35±0.01	3.32±0.02	3.30±0.045	0.052
Glutamic acid	10.52±0.007	10.55±0.04	10.54±0.04	10.50±0.05	0.765
Glycine	3.85±0.05	3.85±0.02	3.83±0.03	3.79±0.035	0.432
Threonine	3.07±0.05	3.11±0.03	3.09±0.03	3.07±0.03	0.765
Serine	3.05±0.03	3.06±0.04	3.03±0.03	2.65±0.37	0.198
Aspartic acid	7.25±0.06	7.26±0.07	7.24±0.07	7.21±0.07	0.891

Interpretation: While minor numerical fluctuations were observed in the amino-acid content over the storage period, these differences were not statistically significant for any of the amino acids measured ($p > 0.05$). The amino-acid profile remained stable.

CHAPTER FIVE

DISCUSSION AND CONCLUSION

5.1. DISCUSSION

In this study, the proximate and mineral composition of Ekpoma rice were analyzed over a period of time and the complete results are shown in table 4.13 and 4.14, respectively. Carbohydrate is the major component of rice grain and it is important in obtaining a significant amount of dietary energy.

According to Table 4.13, the carbohydrate content of Ekpoma rice ranges between 81.30% and 82.60%, which is significantly higher than the recommended dietary intake of 45–65%. In this study, it was observed that Ekpoma rice is mainly composed of carbohydrates, making up about 82% of its dry weight. These carbohydrates serve as the body's main energy source, supporting essential physiological functions. The primary form of carbohydrate in rice is starch, a polysaccharide made up of glucose units. During digestion, starch is broken down into simple sugars that the body uses for energy. Carbohydrates in rice provide several health benefits, particularly as a vital energy source that fuels daily activities and supports metabolism. However, consuming too few carbohydrates can promote body weight loss and improve glycemic control in diabetes, though the long-term effects remain uncertain.

Low-carbohydrate diets (LCDs) may cause mild, temporary weight reduction but are often unsustainable. While beneficial for managing diabetes and insulin resistance, extreme carbohydrate restriction (less than 50 g per day) can lead to side effects such as nausea, fatigue, dehydration, and reduced exercise capacity due to ketosis. Research also shows that diets extremely low (<40% of energy from carbohydrates) or excessively high (>70%) in carbohydrates are linked to increased mortality. Current dietary guidelines therefore recommend replacing refined carbohydrates with unprocessed sources and limiting added sugars.(Arshag, 2020).

The protein content observed in this study is lower than the values reported by (Ebuehi *et al*., 2007), possibly due to prolonged parboiling and environmental or soil (edaphic) factors, but it aligns with the findings of. (Edeogu *et al*., 2007).

Based on Juliano(1993), the average crude protein content of brown rice ranges from 7.1% to 8.3%, and findings from this study reveal that Ekpoma rice has a relatively low protein content. Although rice contains less protein (7.0–9.0 g/100 g) compared to other cereals, its amino acid composition closely resembles that of casein and soy protein, except for its deficiency in lysine (Han *et al*., 2015). Rice protein consists of four main fractions: albumins, globulins, glutelins, and prolamins (Qadir and Wani, 2022a), with glutelin making up about 80% of the total protein in the endosperm and prolamin contributing around 5–10% (Amagliani *et al*., 2017).

The traditional alkaline treatment followed by acid precipitation method is commonly used for extracting rice protein, achieving a recovery rate of over 80% (Paraman *et al*., 2008). This technique is efficient and cost-effective for large-scale protein recovery. The functional properties of rice protein depend on factors such as hydration, molecular structure, surface charge, and processing conditions (Tang and Sun, 2011). Understanding these properties is essential for utilizing rice protein effectively in food formulations, as they influence interactions with other food components (Panyam and Kilara, 1996). Rice protein has potential applications in plant-based protein supplements, sports nutrition, and infant food formulations. (Yadav *et al*., 2011). Despite its nutritional value, the commercial availability of rice protein remains limited.

According to FAO standards, rice must have a moisture content below 14% to ensure safe storage. The moisture level of Ekpoma rice, as presented in Table 4.13, meets this requirement, indicating it is suitable for long-term storage. Moisture content and water activity significantly affect the shelf life and quality of foods (Eke-Ejiofor and Owuno, 2012).

High moisture content promotes microbial growth and chemical reactions that lead to spoilage (Olitino *et al*., 2007; Alozie *et al*., 2009).

Ash content refers to the inorganic residue left after complete oxidation of organic matter and represents the total mineral content of a food. Minerals such as calcium (Ca), sodium (Na), and potassium (K) contribute to this value (Bakkali *et al*., 2009). Generally, a higher ash content indicates greater nutritional richness and flavor in the rice flour.

According to Juliano and Bechtel (1985), who analyzed data from 22 scientific publications, the ash content of rice subjected to conventional milling typically ranges from 0.3% to 0.8%. Other studies have reported similar findings, with average values around 0.5% (Sotelo *et al*., 1990; Scherz *et al*., 2000; USDA, 2004). Findings from Table 4.13 in this study indicate that Ekpoma rice contains a reasonable amount of ash, consistent with these previous reports.

Generally, the ash content of food materials ranges between 0.1% and 2.5% (wet weight basis), and it plays a vital role in the food matrix (Gonca *et al.*, 2016). Ash influences the rheological properties, baking quality, and nutritional value of foods. It is commonly used as an indicator of food refinement, such as in assessing the quality of wheat flour. This is because bran has approximately twenty times higher ash content than the endosperm, allowing ash content to serve as a useful marker in distinguishing between the two. Additionally, minerals in powdered foods increase hygroscopicity (water absorption capacity) through water–mineral and mineral–carbohydrate interactions.

As shown in Table 4.13, Ekpoma rice also contains a relatively high fat content. Rice flours rich in fats are known to enhance flavor and improve the palatability of food products when used in food formulation and processing (Aiyesanmi and Oguntokun, 1996). Fat is an essential nutrient, providing energy, aiding in vitamin transport (particularly fat-soluble vitamins), and contributing to insulation and body protection (Wardlaw and Kkessel, 2002).

The majority of lipids in rice are concentrated in the bran layer, accounting for about 20% (dry basis), while milled rice contains about 1.5–1.7% lipids, primarily non-starch lipids extractable with solvents such as ether or chloroform-methanol (Juliano and Goddard, 1986; Tanaka *et al*., 1978). Protein bodies—especially their cores—also contain notable amounts of lipids (Choudhury and Juliano, 1980; Tanaka *et al*., 1978). The predominant fatty acids found in rice include linoleic, oleic, and palmitic acids (Hemavathy and Prabhaker, 1987; Taira *et al*., 1988). Rice oil contains approximately 29–42% linoleic acid and 0.8–1.0% linolenic acid (Jaiswal, 1983). However, higher grain development temperatures may increase essential fatty acid content while reducing overall oil levels (Taira *et al*., 1979).

The significance of crude fiber has been highlighted by (Islam *et al*., 2007), who found that soluble fiber helps lower total blood cholesterol, while insoluble fiber promotes bowel regularity and reduces the risk of colon cancer. According to Neha and Ramesh (2012), the recommended daily dietary fiber intake is 38 g for men and 25 g for women.

The mineral composition of Ekpoma rice—including calcium, magnesium, sodium, potassium, manganese, zinc, iron, and phosphorus—is presented in Table 4.14. Minerals are vital nutrients essential for the proper functioning of the human body (Xuan *et al*., 2021). They are categorized as macro minerals and micro minerals (trace elements). Macro minerals such as calcium, magnesium, potassium, and phosphorus are required in larger amounts for metabolic processes and must be obtained through the diet since the body cannot synthesize them. Micro minerals, or trace elements, are needed in smaller quantities but are equally important (Vunain *et al*., 2020). In Ekpoma rice, the mean concentration of macro minerals follows the order K > Ca > Mg > Na, while micro minerals follow the pattern P > Fe > Mn, as shown in the table. According to FAO standards(Adeoju *et al*., 2017), the acceptable sodium level in rice is 5.3 mg/kg; however, findings from this study reveal that Ekpoma rice has a higher sodium content than this benchmark.

5.2. CONCLUSION

This study has shown that Ekpoma rice, a type of Nigerian local rice, offers health benefits as a whole grain, including a lower glycemic index compared to polished rice, which helps manage blood sugar for people with type 2 diabetes. It is rich in essential nutrients like fiber, amino-acid, and minerals, and can be a healthier alternative for those avoiding imported, refined rice. As a local rice variety, it also promotes food security and offers a sustainable option for healthier diets.

Therefore, Ekpoma Rice is a good source of different nutrients, and it has the capacity to boost food security, foster rural development and support sustainable land use in Nigeria. The locally produced varieties contained a similar amount of all nutrients analyzed like the foreign varieties. Therefore, the consumption of locally produced rice should be encouraged among Nigerians.

5.3. RECOMMENDATION

Based on the comprehensive analysis of Ekpoma rice and its potential benefits, Ekpoma rice can be considered a valuable addition to diets for patients with Type-2 diabetes having a low glycemic index value which is more slowly digested, absorbed, metabolised, and cause a lower and slower rise in blood glucose and insulin levels. It contains anthocyanin reducing blood sugar levels for Type-2 diabetes. Therefore, consuming Ekpoma rice can support a healthier lifestyle by providing fiber for digestion, antioxidants for cellular health, vital minerals, and energy, while also offering potential anti-aging benefits.

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