EFFECTS OF OKARA FLOUR ADDITION ON THE PHYSIOCHEMICAL AND SENSORY PROPERTIES OF *TUWO SHINKAFA*

BY

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19/10AQ083

A PROJECT WORK SUBMITTED TO THE DEPARTMENT OF HOME ECONOMICS AND FOOD SCIENCE, FACULTY OF AGRICULTURE, UNIVERSITY OF ILORIN, ILORIN, KWARA STATE.

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR OF SCIENCE (B.Sc.) DEGREE IN FOOD SCIENCE

JUNE, 2025

CERTIFICATION

This is to certify that this project was carried out by **FALANA, Oreoluwa Aisha** with Matriculation Number **19/10AQ083** of the Department of Home Economics and Food Science, University of Ilorin, Ilorin, Nigeria for the Award of B.Sc. degree in Food Science during the 2024/2025 Academic Session.

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DEDICATION

I dedicate this work first to God Almighty, for His grace, wisdom, and strength throughout this journey. To my dear mother, whose unwavering love, prayers, and sacrifices have been my greatest support, thank you for everything. And to my late dad, I still carry you with me. Thank you for all you gave while you were here.

ACKNOWLEDGEMENTS

First and foremost, all glory belongs to God Almighty, my ever-present help, the source of my strength, wisdom, and peace. This journey, with all its hills and valleys, would not have been possible without His steady hand and unfailing grace.

To my mum**,** Mrs Elizabeth Bolanle Falana, thank you for loving me fiercely, praying for me endlessly, and sacrificing so much more than words can ever capture. You've been my strength, my shelter, and my greatest cheerleader. I owe more to you than I can say.

To my supervisor, Dr. (Mrs.) A. K. Arise, thank you for your patience, clarity, and thoughtful feedback. Your guidance brought structure and direction to this work, and I deeply appreciate your support throughout the process. My heartfelt appreciation also goes to the Head of Department, Home Economics and Food Science, Professor Mrs. O. A. Abiodun, as well as to Professor R. M. O. Kayode, Professor Mrs. Balogun, Professor Mrs. Kolawole, Dr. Dauda, Dr. Raji, and Mrs. Salami. Thank you all for the significant impact you made during my time in this institution.

To my brothers, Opeyemi, Ayomide, Kolawole, and Tomiwa, your love and belief in me have been a quiet strength that carried me through. And to my grandma and cousins, especially Uncle Debo and Aunty Bolaji, thank you for showing up with kindness. To Uncle Taju**,** your presence has filled spaces that words cannot fully honor.

To my sweet friend Praise, thank you for holding space for me in the quiet ways that matter most, for standing close, even in the moments when I didn't know how to be fully present. Your friendship has been one of my safest places. To my wonderful friends in the same department, Khadijat, Divine, and James, meeting you in 300 level was one of the greatest gifts of this journey. You made this journey lighter and brighter, and I'm so glad I found you.

To my dear family at RCF Commercial Unit, you may have started as Unit members but you became friends, real friends. Thank you for every shared laugh, prayer, and hug. To every friend God has planted along this path, thank you for your joy, your support, and for simply being there.

I'm also grateful to the Desci Nigeria Community for their support towards this project, your contribution made a real difference and I appreciate it.

And to everyone who held me up in the quiet, unseen moments, thank you. You may never fully know how much it meant, but I do.

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ABSTRACT

The growing demand for nutrient-enriched traditional foods and sustainable food processing has led to the exploration of okara, a soybean by-product, for its nutritional and functional benefits. *Tuwo shinkafa*, a rice-based staple widely consumed in Northern Nigeria, is rich in carbohydrates but low in protein and fiber. This study investigated the effect of okara flour addition on the physicochemical, functional, and sensory properties of *Tuwo shinkafa*. Rice flour was substituted with okara flour at 5%, 10%, 15%, 20%, and 25% levels, alongside a 100% rice flour control. The flour blends were evaluated for proximate composition, functional and pasting properties, while the final *Tuwo* samples were assessed through sensory evaluation. Results showed that okara addition significantly enhanced protein (up to 9.56%), fiber (3.44%), fat (2.85%), and ash content, while carbohydrate levels declined from 79.42% in the control to 63.41% in the 25% okara blend. Functional analysis revealed improved water absorption capacity and swelling index, contributing to better consistency. Among all samples, the 10% okara blend (TUC) was rated highest in taste, texture, and overall acceptability by sensory panelists. In conclusion, the inclusion of okara flour in *Tuwo shinkafa* offers a sustainable approach to enhancing its nutritional value while maintaining consumer appeal. This study supports the valorization of agro-industrial by-products to improve local diets and reduce food waste.

CHAPTER ONE

INTRODUCTION

1.1 Introduction

Tuwo shinkafa is a popular meal in the northern part of Nigeria from where it is believed to have originated. It is usually made by mixing non-parboiled, soft, sticky white rice flour with boiling water and stirred until a smooth consistency gel is formed. This gel, moulded into a spherical shape, is usually consumed with accompaniment including soups such as *Miyan kuka* (Falade and Christopher, 2015).

1.2 Background of Study

Rice (*Oryza sativa*) which is the main raw material in *Tuwo shinkafa* production is a cereal of great importance in both developing and developed worlds. It is a semi-aquatic, annual grass plant which has been reported to contain substantial amount of carbohydrate, vitamins such as thiamine, niacin and riboflavin, minerals and little amount of protein and fat (Umadevi *et al.*, 2012). It is also gluten and cholesterol free. The production and consumption of rice as a major dietary source of energy is at large in Nigeria and the use of rice flour as a staple food is on the increase worldwide. This staple food provides 700 calories/day-person for about 300 million people of the world's population (Vlachos and Arvanitoyannis, 2008).

Okara, is the residue obtained from ground soybean after removing the water-extractable fraction used to produce tofu or soymilk (Santos *et al.,* 2019). It is also called soybean paste, it is yellowish white with a neutral, smooth flavor. It consists of an insoluble fraction obtained from the hydrothermal treatment of the crushed soybean. It has a rich array of nutritional components, containing 40%–65% dietary fiber, 25% protein, and 10% oil (dry basis). It also contains all essential amino acids, making them a good source of nutrition (Tang *et al.*, 2021). In addition, okara can supply the limiting amino acids in cereal foods, especially lysine. As a result, okara has gained global attention due to its favorable chemical composition in recent years (Asghar *et al*., 2023). Additionally, studies have verified that okara's dietary fiber content possesses hypolipidemic, hypoglycemic, and antioxidant properties.

1.3 Justification of Study

Investigation on utilization of underutilized food resources or edible by-products of food industries is a promising alternative to address the aggravating world food problem prevailing in the developing countries including Nigeria. The global production of soybean okara amounts to about 1.4 billion tons per year, but it is underutilized considering the potential nutritional benefits of okara, causing significant environmental pollution (Mok *et al.,* 2020).

Soybean and its by-products provide affordable protein sources that are rich in nutrients (Canaan *et al.,* 2022). Increased soybean production worldwide has resulted in a growth in the popularity of soy-based foods (i.e., tofu, soymilk and soy nuts) (Messina, 2016). On the other hand, significant wastes/by- products are generated during the processing of soybeans such as soybean okara. Industries frequently underuse okara, despite its high nutritional content (Asghar *et al.,* 2023).

The inclusion of okara flour in *Tuwo shinkafa* could increase its nutritional value, offering higher protein content, additional fiber and a range of essential minerals and vitamins. Soy protein, in particular, is known for its positive effects on cardiovascular health, while fiber supports digestive health (Asghar *et al.,* 2023). This could contribute to improving the nutritional status of individuals who rely on staple foods such as *Tuwo shinkafa*, which are often low in protein and micronutrients.

In addition to its nutritional benefits, okara's potential to improve the texture and consistency of *Tuwo shinkafa* warrants investigation. Okara flour has been shown to have water-holding and gel-forming properties which are essential for the desired texture in food products (Belghith-Fendri *et al.,* 2016). These properties could enhance the mouthfeel and overall sensory qualities of *Tuwo shinkafa*, making it more appealing to consumers.

By transforming okara into a functional ingredient, this study hopes to provide a new, sustainable approach to improving the nutritional profile and functional properties of this popular dish, benefiting both local communities and the broader food industry. It aligns with sustainable food practices, promoting a circular economy within food production systems.

1.4 Objectives of the Study

The general objective of the study is to produce and assess the quality of *Tuwo shinkafa* fortified with okara flour.

The specific objectives were to:

- Determine the Proximate composition of the rice-okara flour blends
- Determine the Physicochemical properties of the rice-okara flour blends
- Determine the Functional properties of the rice-okara flour blends
- Determine the Pasting properties of rice-okara flour blends
- Determine the Amino acid composition of the rice-okara flour blends
- To evaluate the organoleptic properties of *Tuwo shinkafa* prepared from the rice–okara flour blends

CHAPTER TWO

LITERATURE REVIEW

2.1 Origin of Rice

Rice is an important cereal crop in the developing world and is the staple food of over half the world's population. It is estimated that more than 3.5 billion inhabitants depend on rice for obtaining 20% of their daily calorie intake (IRRI, Africa Rice and CIAT, 2010). It is of crucial importance in providing food security for an exponentially growing population. The geographical site of the origin of rice domestication is not yet definitely known. The general consensus is that rice domestication occurred independently in China, India and Indonesia. About 20 species of the genus *Oryza* are recognized, but nearly all cultivated rice is *O. sativa L.*

The most widely cultivated rice species in the world belong to two cultivated types, the universally cultivated Asian rice, Oryza sativa *L*. and the African rice, *O. glaberrima Steud*. The latter species belongs to tropical West Africa. Its commercial cultivation has now all but disappeared and it has been replaced by the higher yielding, more adaptable Asian rice (Nayar, 2010). It is believed that rice from Asia migrated to Africa by a number of different routes at different times, and expanding trade networks between Asia and areas of East and West Africa are thought to have contributed to the introduction of *O. sativa* to Africa via two potential marine routes in the fifteenth and sixteenth centuries. Prior to the introduction of *O. sativa* from Asia, the only cultivated species found in Africa was *O. glaberrima*, which is valued for its resilience in challenging conditions, including drought tolerance and pest resistance (Babatunde *et al.*, 2024).

Asian and African rice have distinct phenotypic characteristics: their grains differ in colour, size, shape and taste. Whereas Asian rice can be milled mechanically, facilitating large-scale production, African rice grains break easily and have to be milled manually with a mortar and pestle. These characteristics have favoured the cultivation of Asian rice over African rice in large parts of the world (Veltman *et al.*, 2019). But the *O. glaberrima* types also offer distinct advantages: the plants have luxurious wide leaves that shade out weeds and the species is more resistant than its Asian cousin to diseases and pests. Moreover, African rice is better at tolerating fluctuations in water depth, iron toxicity, infertile soils, severe climates, and human neglect (Wambugu *et al*., 2019)

Because of its long history of cultivation, Cultivars of *Oryza sativa* with resistance to aluminum toxicity and with tolerance to submergence by flood water high salinity and cool temperatures at the seedling or ripening stage have been developed in Asia. In Africa, cultivars with tolerance to iron toxicity and heat constraints have also been developed and cultivated (IRRI, 2014). The ease of cultivation and processing of *O. sativa* ensures its availability as a staple food, meeting the dietary needs of billions. Despite the advantages of African rice (*O. glaberrima*), its lower yield and challenges in mechanized processing have limited its widespread commercialization.

2.1.1 Structure of the Rice Grain

- **Hull**

  The mature rice grain is harvested as a covered grain (rough rice or paddy), in which the caryopsis (brown rice) is enclosed by a tough siliceous hull (husk) (Juliano and Tuano, 2019). The caryopsis is enveloped by the hull, composed of two “modified” leaves (lemmae): the palea (dorsal) and the larger lemma(ventral).

  The palea and lemma are held together by two hook-like structures. The shape of the mature caryopsis and its ridges correspond to the shapes of the lemma and palea. The outer surface of the hull possesses trichomes that fit between longitudinal rows of endosperm cells. Some varieties have an awn attached to the tip of the lemma. The cells of the hull are highly lignified and brittle. Mean hull weight is about 20% of the rough rice weight, with values ranging from 16% to 28%.

The rice hull provides protection to the caryopsis. The tightness of the hull, or the ability of the lemma and palea to hook together without gaps, has been related to the grain's resistance to insect infestation during storage. The hull also protects the grain from fungi infestation, as the dehulled grain can readily be colonized *by Aspergillus spp.*

- **Pericarp, seed coat and nucellus**

The caryopsis of rice is a single-seeded fruit in which the pericarp is fused with the seed, which includes the seed coat, nucellus, endosperm, and embryo. Within the hull, the mature rice grain has three distinct layers forming the caryopsis coat: the pericarp, seed coat (tegmen), and nucellus, which enclose the endosperm and embryo. The pericarp, the mature ovary wall, undergoes significant degeneration during caryopsis development. It consists of multiple layers of crushed cells approximately 10µm thick and contains a single vascular bundle on its dorsal side. Its outer surface is uneven and covered by a thin cuticle. Adjacent to the pericarp lies a single layer of crushed cells known as the seed coat or tegmen. The seed coat has a thick inner cuticle (about 0.5µm thick), derived from the inner layer of the inner integument. Pigments in colored rice varieties are usually found in the pericarp or seed coat, contributing to differences in pigment retention after milling. Next to the seed coat is another layer with a thick cuticle (0.8µm thick), originating from the crushed nucellar cells (Juliano and Tuano, 2019). The nucellus in mature rice measures around 2.5µm thick, including its cuticle. The bond between the seed coat and nucellar cuticle is weak, leading to their separation during tissue handling and preparation.

- **Aleurone layer**

The aleurone layer, the outermost layer of the endosperm (triploid tissue), differs in both morphology and function from the starchy endosperm. It may be 1-7 cells thick and is thicker on the dorsal (back) than along the lateral (side) and ventral (front, embryo side) surfaces. Varieties differ in the thickness of the aleurone layer; coarser or bolder, short-grain rices tend to have more cell layers than do slender, long-grain rices. The aleurone layer completely surrounds the rice grain and the outer side of the embryo. It is tightly bound to the underlying cells of the starchy endosperm and to most of the embryo. Two types of aleurone cells are reported (Zheng *et al*., 2017). Those of the first type, around the starchy endosperm, are cuboidal and are densely packed cytoplasm. Here, two storage structures are prominent: aleurone grains (protein bodies [PBs] or aleurins) and lipid bodies (spherosomes). Aleurone grains are membrane-bound and contain globoids, which are 1-3 µm phytate storage bodies. Globoids prepared in 1.25-1.35 g/mL density media are spherical particles about 2-3 µm in diameter (Juliano and Tuano, 2019).

Lipid bodies are apparently not bound by a typical bilayer membrane, are homogeneous, and are able to fuse with one another following mechanical damage of the grain. Surface proteins called oleosins maintain the integrity of seed oil bodies by negatively charged repulsion and steric hindrance. Rice oleosins have isoelectric point of pH 6.2 and are present in 16 and 18 kDa isoforms. Rice oil bodies lose their integrity on trypsin treatment. Other organelles of the aleurone layer include the nucleus, mitochondria, endoplasmic reticulum, vesicles, and plastids. Plastids are bound by a double membrane and are unique in that they possess invaginations that form vesicles and tubules of cytoplasm within the plastid. The second type of aleurone cells that surround the embryo has been termed the modified aleurone layer. It differs substantially from the other aleurone cells in that the modified cell has less densely packed cytoplasm, is rectangular, has fewer and smaller lipid bodies, lacks aleurone grains, has numerous vesicles, and has filament bundles (Zheng *et al.,* 2017).

- **Embryo**

The embryo, or germ, is a tiny structure situated on the ventral side at the base of the grain. It is enclosed by a single aleurone layer and the fibrous remnants of the pericarp, seed coat, and nucellus, collectively forming the caryopsis coat. The starchy endosperm lies adjacent to the inner boundary of the embryo. The embryo consists of two main components: the scutellum (cotyledon) and the embryonic axis. The C-shaped embryonic axis is separated from the starchy endosperm by the scutellum, which itself contains globoid-rich particles similar to aleurone grains. Three appendages of the scutellum partly sheath the coleoptile; a ventral scale and two lateral scales protect the upper half of the axis (Juliano and Tuano, 2019).

In a longitudinal section, the embryonic leaves (plumule) and the primary embryonic root (radicle) are visible, connected by a short stem known as the mesocotyl. The lower part of the embryonic axis is encased by the epiblast, an upper extension of the coleorhiza, which surrounds the radicle and merges seamlessly with the scutellum proper. The radicle itself is composed of the root cap, root apex, epidermis, subepidermal region (hypodermis), cortex, endodermis, pericycle, and provascular tissue. A small section of parenchyma cells and interconnecting tissues, the mesocotyl, separates the radicle from the plumule. The plumule is encased and safeguarded by a cone-shaped structure called the coleoptile, whose cells are rich in protein and lipid bodies.

- **Endosperm**

The endosperm cells are thin-walled and packed with amyloplasts containing compound starch granules. The two outermost cell layers (the subaleurone layer) are rich in protein and lipid and have smaller amyloplasts and compound starch granules than the inner endosperm. The starch granules are polyhedral and mainly 3 to 9 µm in size, with unimodal distribution. Protein occurs mainly in the form of spherical protein bodies 0.5 to 4 µm in size throughout the endosperm), but crystalline protein bodies and small spherical protein bodies are localized in the subaleurone layer. Both PB-I and PB-II are distributed throughout the rice endosperm. Non-waxy rice (containing amylose in addition to amylopectin) has a translucent endosperm, whereas waxy (0 to 2 percent amylose) rice has an opaque endosperm because of the presence of pores between and within the starch granules. Thus, waxy grain has about 95 to 98 percent the grain weight of non-waxy grain.

2.1.2 Gross Nutrient Composition

Among cereal grains, brown rice has the lowest protein and total dietary fiber content but it has the highest starch and available carbohydrate content (USDA, 2016). It ranks second only to oats in energy content. The fiber content of brown rice is reduced when the inedible hull is removed. The low fiber content of brown rice delayed its recognition as a whole grain by the United States Food and Drug Administration, which typically requires at least 10% dietary fiber content in whole grains. In brown rice, non-starch components are concentrated in the bran, while the endosperm (milled rice) is primarily composed of starch. Lipid bodies are most abundant in the embryo and aleurone layer, and also present in the subaleurone layer. Among the milling fractions of rice, the bran has the highest energy and protein content and the hull has the lowest; hence, the energy level is highest in the bran, followed by brown rice, and then milled rice (Champagne *et al.,* 2004). The protein content in brown rice is slightly higher than in milled rice due to the protein-rich bran. The B vitamins are concentrated in the bran layers, as is α-tocopherol (vitamin E). The rice grain has no vitamin A, vitamin D or vitamin C.

Additionally, brown rice has greater levels of crude fat, crude ash, crude fiber, total dietary fiber, sugars, phytic acid, and phenolics compared to milled rice, all of which are concentrated in the bran. The minerals (ash) are also concentrated in the outer layers of brown rice or in the bran fraction. A major proportion (90 percent) of the phosphorus in bran is phytin phosphorus. Potassium and magnesium are the principal salts of phytin. The ash distribution in brown rice is 51 percent in the bran, 10 percent in the germ, 10 percent in the polish and 28 percent in the milled rice fraction; iron, phosphorus and potassium show a similar distribution.

However, some minerals show a relatively more even distribution in the grain: milled rice retained 63 percent of the sodium, 74 percent of the calcium and 83 percent of the Kjeldahl N content of brown rice (Juliano and Tuano, 2019). Pigments in rice are found in the pericarp. Black or purple rice has a higher phenolic content (0.6% anthocyanins) than red rice (0.2% proanthocyanidins), while non-pigmented brown rice contains less than 0.02% phenolics (Shao *et al.,* 2014). Anthocyanins and proanthocyanidins have both been identified in black rice (Finocchiaro *et al.,* 2010). Antioxidant activity is significantly higher in raw pigmented rice than in non-pigmented rice, both in free and bound forms (Irakli *et al.,* 2016).

2.1.3 Variety of Rice

- **White Rice**

  White rice is characterized by a moderately white kernel and a translucent endosperm. It typically has long grains over 7.0 mm in length and a length-to-width ratio exceeding 3.0.

After cooking, the grains become tender yet firm, with no noticeable aroma. It is highly versatile and can be used in a wide range of dishes (BERNAS, 2022).

- **Brown Rice**

  Brown rice, also called hulled or unmilled rice, retains its bran layers and embryos, which contain beneficial bioactive compounds like dietary fiber, oryzanol, vitamins, and minerals. Unlike white rice, brown rice is consumed less frequently due to its coarser texture when cooked. It has a mild, nutty flavor and a chewy texture. Brown rice is often used in fried rice recipes and pairs well with vegetables or beans. Its cooking process takes longer because the bran layer impedes water absorption (Cho and Lim, 2016).

- **Fragrant Rice**

  Fragrant rice is well-known for its distinct aroma, primarily due to the presence of 2-acetyl-1-pyrroline (2AP). The formation of this aroma is influenced by compounds like nithine, proline, and acetyl groups. Several enzymes, such as P5CS, diamine oxidase, OAT, and proline dehydrogenase, are involved in the synthesis of 2AP, contributing to its signature fragrance (Xie *et al.,* 2021).

- **Basmati Rice**

  Basmati rice is a fragrant variety that is highly regarded for its pleasing aroma, making it a favorite in cooking (Singh *et al.,* 2018). It is a long, slender grain originating from India and Pakistan but is now cultivated worldwide (Bera, 2020). Although white in color, it has a slight curve in its blade shape. When cooked, it expands almost twice its original size, emits a subtle fragrance, and retains a light, separated texture (Prodhan and Qingyao, 2020).

- **Ponni Rice**

  Ponni rice, which has a short, plump, nearly round kernel, is firm yet slightly springy when cooked (Ramasamy, 2020). This rice variety, originating from India, is commonly used for everyday meals and is often paired with flavorful dishes like spicy curries, making it popular in Indian cuisine (Ramchander *et al.,* 2015).

- **Glutinous or Waxy Rice**

  Glutinous rice, grown in various countries including Laos, Japan, China, Thailand, Vietnam, Myanmar, Bangladesh, Cambodia, Malaysia, and India, is primarily consumed as a staple food in Laos. It is typically served as a breakfast cereal or dessert and is steamed or folded in banana leaves. Due to its unique starch composition, glutinous rice requires specific processing methods, such as tempering and parboiling, to enhance grain quality and milling efficiency (Nawaz, 2018).

- **Red Rice**

  Red rice, commonly used in Asian cuisines, can be either fully or partially hulled. It shares a similar nutritional profile with brown rice but has higher antioxidant content compared to white rice (Agustin *et al.,* 2021). Red rice offers a nuttier, chewier, and sweeter taste, making it a great alternative to white rice. Its cooking time is longer, but soaking the rice for 30 minutes beforehand can soften it and reduce cooking time.

- **Japonica Rice**

  Japonica rice is a staple in Japan, recognized for its short, plump grains that are slightly translucent when uncooked. It is soft, moist, and sticky when cooked, with a lower amylose content than Indica rice (Gong *et al.,* 2021). Japonica rice absorbs flavors well and is commonly used in sushi and other Japanese dishes, contributing significantly to their flavor.

- **Weedy or Red Rice**

  Weedy rice, also known as red rice, is an undesirable plant that poses a threat to rice farming worldwide. It resembles cultivated rice (Ratnasekera, 2015) but can be distinguished by characteristics such as a long, weak stem, diverse grain shapes, and red pericarp (Dimotrovski *et al.*, 2018). Weedy rice also has higher seed dormancy and shattering seeds, making it challenging to manage in rice fields.

- **Golden Rice**

  Golden rice is a genetically modified crop designed to combat vitamin A deficiency, especially in developing countries where rice is a primary food source (De Steur *et al.,* 2022). Its yellow color comes from the presence of beta-carotene, a precursor to vitamin A. Golden rice shows similar pest resistance and yield performance to regular rice, and it is considered an affordable solution to improving vitamin A intake (Rodriguez *et al.,* 2022). Research has shown that certain lines of Golden rice can meet up to 50% of the average daily vitamin A requirement.

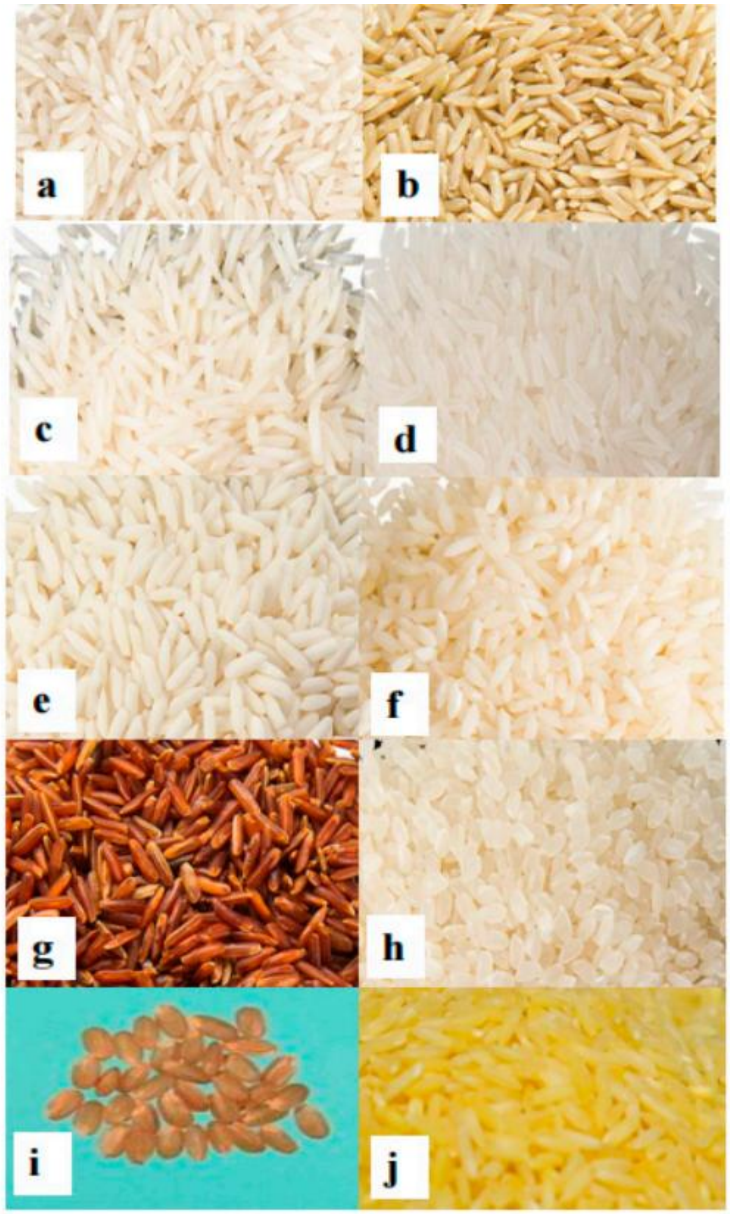

Figure 2.1: The various varieties of rice**:** (a) white rice, (b) brown rice, (c) basmati, (d) fragrant rice (e) glutinous rice, (f) ponni rice (g), red rice, (h), japonica rice, (i) weedy or red rice, and (j) golden rice

Source: (Mohidem *et al.,* 2022)

2.1.4 Nutritional Value of Rice

White rice is derived from brown rice by removing the bran and germ layers through milling and polishing. This processing reduces the natural fiber and nutrient content of the rice. In contrast, unrefined rice (brown rice), retains its nutrient-dense bran and germ, making it a richer source of dietary fiber, vitamins, and minerals (Ranajit *et al.,* 2019). Brown rice contains protein, essential fatty acids, and a range of micronutrients, including magnesium, phosphorus, and manganese, which play vital roles in supporting digestion, strengthening bones, and enhancing metabolic functions.

Although processed rice (white rice) loses some of its original nutritional value, it is often enriched with key vitamins such as thiamine (B_1), niacin (B_3), and folate. These added nutrients help maintain nervous system health and support overall cellular function. A team of Japanese researchers found that germinated brown rice had higher lysine content, food fibre and anti-oxidants than white rice. Germinated brown rice, with rich gamma amino butyric acid (GABA), appears to be effective in normalizing blood pressure, and controlling glycemia and cholesterol in the blood. It has the potential to activate brain cell metabolism, prevent cancer and Alzheimer's disease, and eliminate anxiety disorders (Chaudhari *et al,* 2018).

According to the United States Department of Agriculture (USDA) National Nutrient Database, rice provides essential nutrients that make it a valuable staple in diets worldwide. One cup of cooked, enriched, long-grain white rice contains approximately 205 kilocalories, 4.25 grams of protein, 0.44 grams of fat, 44.51 grams of carbohydrates, and 0.6 grams of dietary fiber. On the other hand, one cup of cooked, long-grain brown rice offers 248 kilocalories, 5.53 grams of protein, 1.96 grams of fat, 51.67 grams of carbohydrates, and 3.2 grams of dietary fiber.

Table 2.1: **Values of vitamins and minerals in 1 cup of cooked, long-grain white or brown rice**

Vitamin/Mineral	Percent daily value provided by white rice	Percent daily value provided by brown rice
Iron	11	6
Thiamine	17	24
Niacin	12	26
Vitamin B_6	7	12
Folate	38	5
Phosphorus	7	21
Magnesium	5	20
Zinc	5	10
Selenium	17	17
Copper	5	11
Manganese	37	98

Source: Ranajit *et al.* (2019)

2.1.5 Nutritional Problems in Rice-Consuming Countries

Despite its importance as an energy source, rice has limitations in nutrient diversity which can lead to nutritional deficiencies in populations that rely heavily on it as their primary food. A large number of persons living in predominantly rice-eating countries suffer from various forms of malnutrition

- **Protein-energy malnutrition**

  Protein-energy malnutrition (PEM) remains a significant public health challenge in many developing regions, particularly in countries where diets are predominantly starchy (Temba et al., 2016). It is widespread in numerous rice-consuming nations, with low-income countries being the most severely impacted. PEM is commonly observed as growth retardation in preschool-aged children. In rice-consuming countries such as India, Laos, Madagascar, Nepal, Sierra Leone, Sri Lanka, and Vietnam, PEM is a critical factor contributing directly or indirectly to high mortality rates among children under five.

- **Vitamin A deficiency**

  Vitamin A deficiency (VAD) is prevalent in populations that primarily consume rice. It continues to be a significant public health issue in over half of the countries, particularly in Africa and Southeast Asia, where it most severely affects young children and pregnant women. This problem is especially prominent in regions where rice serves as the staple food, as affordable staple crops like rice dominate the diet, limiting the intake of other nutrient-rich foods (Majumder *et al.,* 2019).

- **Thiamine and riboflavin deficiency**

  Food processing methods can significantly impact the thiamine content of foods, and rice processing is particularly important in this context. Thiamine deficiency disorder (TDD) such as Beriberi, is commonly found in regions where polished rice is a dietary staple. In many rice-consuming countries, polished white rice is preferred for cultural reasons (e.g., white rice is seen as a status symbol and has more appealing taste and texture) and economic reasons (e.g., removing the lipid-rich outer bran extends shelf life and reduces cooking time and resource use). There are also financial incentives for rice millers to thoroughly polish rice, as the rice bran is often sold as animal feed. In some areas, like rural Cambodia, rice millers do not charge farmers for milling services but instead keep the rice polishings, which they sell as animal feed. This model encourages rice millers to fully mill the rice to maximize the quantity of bran they can sell. Although rice naturally contains thiamine in its outer husk and bran layers, these components are lost during the milling process, reducing the thiamine content of the rice (Whitfield *et al.,* 2018).

Similarly, Riboflavin deficiency is also a prevalent issue in many developing countries, especially in areas where rice is the primary staple food and where there is insufficient intake of other important sources of riboflavin, such as milk and meat (Leblanc *et al.,* 2011). This deficiency can lead to various health problems, including fatigue, skin disorders, and eye issues, making it a significant public health concern in these regions. Angular stomatitis, a clinical sign often attributed to riboflavin deficiency, is also frequently seen in young children, pregnant women and lactating mothers in rice-eating populations in Bangladesh, India and Thailand.

- **Iodine deficiency disorders**

Iodine deficiency is a significant issue among populations whose primary staple food is rice (Bhullar and Gruissem, 2013). Iodine Deficiency Disorder (IDD) is particularly common in rice-eating communities, especially in mountainous regions of countries like

Brazil, China, India, Indonesia, and Malaysia, where iodine levels in soil, water, and food are naturally low. Iodine plays a crucial role in supporting normal growth, fetal development, and physical and mental activities in adults. Beyond the obvious signs of IDD, iodine deficiency can lead to various adverse effects, including reduced cognitive abilities, persistent lethargy, higher rates of stillbirths, and increased infant mortality.

- **Nutritional Anaemia**

  Nutritional anemia, primarily caused by iron deficiency, is widespread in many rice-consuming countries. Rice, being one of the cereals lowest in iron, typically contains only 5 to 6 mg/kg after milling (Meng *et al.,* 2005). This deficiency is often due to low dietary iron intake and the poor bioavailability of iron from food sources. The highest prevalence of anemia in developing regions is observed in South Asia and Africa. Anemia is a significant contributor to maternal mortality during childbirth. Additionally, in adults, it impairs work performance and weakens immune function, making individuals more susceptible to infections. Even mild anemia can have profound effects on psychological well-being and cognitive development, further emphasizing its impact on public health.

2.1.6 Major Processed Rice Products

Beyond its role as a cooked dish, rice undergoes various forms of processing to create an array of valuable products that serve diverse purposes in food, industry, and agriculture. One of the primary processed rice products is **rice starch**, widely used in the food industry for making ice cream, custard powder, puddings, and gels. It also plays a crucial role in the distillation of potable alcohol. Similarly, **rice bran**, a by-product of rice milling, is incredibly versatile. It is incorporated into confectionery products such as bread, snacks, cookies, and biscuits. Defatted rice bran serves as cattle feed, organic fertilizer, and even finds applications in medicinal formulations and wax production.

Another significant product is **rice bran oil**, which stands out for its nutritional benefits and heart-protective properties. This edible oil is also used in the production of soap, fatty acids, synthetic fibers, detergents, and cosmetics. The oil's multifunctional nature underscores the value of rice in non-food industries. Processed rice also caters to diverse culinary needs. **Flaked rice**, made from parboiled rice, is a staple ingredient in many traditional dishes, while **puffed rice**, derived from paddy, is popular as a snack or breakfast cereal. **Parched rice**, also produced from parboiled rice, is notable for being lightweight and easily digestible, making it a preferred food choice in various regions. Rice by-products extend their utility to non-food applications as well. **Rice husk**, a residue of rice processing, is used as fuel and in the manufacturing of boards, paper, packing materials, and building supplies. It also serves as an insulator and a component for composting and chemical derivatives. Similarly, **broken rice**, a by-product of milling, is transformed into breakfast cereals, baby food, rice flour, noodles, and rice cakes, while also being a popular poultry feed.

Lastly, **rice straw**, an often-overlooked by-product, is utilized as animal feed, fuel, and mulch for horticultural crops. It also serves as a growing medium for mushrooms, further showcasing the agricultural significance of rice processing (Chaudhari *et al.,* 2018). Rice is not merely a staple food but a versatile crop that gives rise to a wide variety of processed products.

2.2 Soybeans

Soybean (*Glycine max*) is a key global source of vegetable oil and is highly valued for its nutritional benefits and economic significance. The cultivation of soybeans originated in Asia around 5000 years ago, initially in China, followed by Japan. It later spread to Europe in the 18th century and to the United States in the 19th century (Valliyodan *et al.,* 2016). Due to its rich content of vegetable oil and protein, soybean has become an economically important crop worldwide (Singh et al., 2020). With the projected rise in population and purchasing power, particularly in developing countries, especially in Asia, the demand for soybean is expected to increase significantly in the coming years. By 2050, the global population is estimated to reach 9 billion, creating a demand for 333.674 million tons of food (Alexandratos and Bruinsma, 2012). Besides its industrial applications, soybean plays a crucial role in animal feed (Singh *et al.,* 2020), and its demand will continue to rise (Silva *et al.,* 2018). Soybean is commercially cultivated as a major oilseed crop in around 35 countries (Kamshybayeva *et al.,* 2017).

Soybeans typically consist of 35-40% protein, 20% lipids, 9% dietary fiber, and around 8.5% moisture by dry weight of mature raw seeds, although this composition can vary depending on factors such as location, climate, and soybean variety (He *et al.,* 2013). Soy foods are an excellent source of minerals, proteins, fibers, and vitamins, and are low in saturated fats. A wide variety of soy-based products are produced, including roasted and boiled soybeans, soy milk, soy mayonnaise, miso, soy cheese, soy yogurt, tempeh, soy sauce, tamari, Textured Vegetable Protein (TVP), Textured Soy Protein (TSP), and tofu (Jayachandra and Xu, 2019). The biologically active components in soybeans include proteins and peptides, saponins, isoflavones, and protease inhibitors (Asif and Acharya, 2013). Soybeans and their products are widely consumed for their health benefits, primarily due to their high content of isoflavones and folic acid. These products are essential sources of plant protein, as they contain a significant amount of essential amino acids, offering numerous health advantages. Additionally, the polyunsaturated fatty acids and healthy fats in soybeans are important from a nutraceutical perspective (Kamshybayeva *et al.,* 2017). Soybeans also provide substantial amounts of calcium, iron, and zinc, with mineral content (5%) significantly higher than that of cereal seeds (1%) (Kahraman, 2017). Furthermore, soy proteins contain bioactive peptides that help prevent age-related chronic diseases, such as obesity, weakened immune function, cardiovascular diseases, and cancer.

2.3 Okara

Soybeans are commonly processed to produce protein isolates and other derivatives, such as soymilk and soybean curd (tofu) (Villanueva-Suárez *et al*., 2016). These are traditional Asian food products that have gained global popularity due to their nutritional benefits and health-promoting properties. One by-product of soymilk and tofu production is a fibrous residue known as okara, which is obtained after the extraction of the aqueous fraction. Okara is a white-yellow substance made up of the insoluble parts of soybean seeds that remain in the filter sack after the pureed seeds are strained during soymilk preparation. Rich in nutrients, okara has been part of vegetarian diets in Western countries since the 20th century. Research indicates that it contains a significant amount of proteins, isoflavones, soluble and insoluble fibers, soyasaponins, and essential minerals, all of which are associated with various health benefits (Li *et al.,* 2013). Its high dietary fiber content has been associated with weight reduction, improved lipid metabolism, better gut health through antioxidant properties, and prebiotic effects (Swallah *et al.,* 2021).

From 1 kilogram of dry soybeans processed into soymilk or tofu, approximately 1.2 kilograms of wet okara is generated, making it an affordable and fiber-rich food source (Lesa et al., 2023). However, its potential is underutilized, as okara is often discarded as waste, used as fertilizer, animal feed, or sent to landfills (Feng et al., 2021). This is largely due to its high moisture content, which makes it prone to spoilage, along with additional production costs, an undesirable flavor, and a gritty texture that limit its broader use.

Figure 2.2: Okara

Source: (Stephan, 2025)

2.3.1 Production Technology

The composition of okara is influenced by the amount of water used during the extraction process from ground soybeans, as well as the specific production method employed. Soymilk production generally follows two main techniques: the Chinese method and the Japanese method, which differ only slightly in their processes. In the Chinese method, soybeans are soaked, rinsed, ground, heated, and then filtered to produce soymilk. Conversely, the Japanese method involves soaking, rinsing, heating, grinding, and filtering the soybeans (Asghar *et al.,* 2023). In both cases, the solid residue left after filtration is referred to as okara (Guimarães *et al.,* 2018). (Guimarães 2018) Okara is a globally produced by-product of soybean processing. For every kilogram of tofu made from soybeans, approximately 1.2 kilograms of fresh okara is generated (Lesa et al., 2023). Tofu industries contribute significantly to okara production, with annual estimates of around 800,000 tons in Japan, 310,000 tons in Korea, and 2,800,000 tons in China (García-Alonso *et al.,* 2022).

2.3.2 Nutritional Composition

Fresh okara has a high moisture content, which makes it highly perishable, and is also rich in dietary fiber (Lesa *et al*., 2023). It serves as an excellent source of protein and carbohydrates. Among the essential fatty acids found in okara are linoleic acid, palmitic acid, stearic acid, oleic acid, and linolenic acid. Okara also contains various sugars, including monosaccharides, oligosaccharides, and polysaccharides such as arabinose, glucose, galactose, fructose, stachyose, raffinose, sucrose, and starch (Vong and Liu, 2016). In addition, okara is rich in phytochemicals like phytates, saponins, coumestans, phytosterols, lignans, and isoflavones (notably genistein and daidzein) (Kumar *et al*., 2016). These compounds exhibit numerous therapeutic and physiological benefits, including antioxidant properties, cardiovascular disease prevention, and chemopreventive effects for cancer patients (Li *et al.,* 2012). Okara is also mineral-rich, with every

100 grams containing approximately 126 mg of calcium, 4.45 mg of iron, 0.77 mg of copper, 313 mg of phosphorus, 286 mg of potassium, and 3.14 mg of zinc (Kamble & Rani, 2020).

The diversity in soybean varieties, such as black and yellow soybeans, results in different forms of okara with varying chemical compositions (Anjum *et al*., 2022). Okara is particularly valued for its high dietary fiber content, which plays a crucial role in various physiological processes and in preventing health issues (Li *et al.,* 2012). Dietary fiber is categorized into four types: crude fiber (CF), total dietary fiber (TDF), insoluble dietary fiber (IDF), and soluble dietary fiber (SDF) (Brownlee, 2011). Like many vegetable by-products from the food industry, okara is rich in insoluble dietary fiber but low in soluble dietary fiber (Lesa *et al*., 2023).

Table 2.2: Chemical composition of wet okara, dried okara, black soybean okara, and yellow soybean okara

Chemical components	Wet okara	Dried okara	Black soybean okara	Yellow soybean okara
Moisture (%)	68.03	1	6.44	3.41
Fat (%)	6.02	12.6	16.46	7.21
Protein (%)	8.08	34.15	34.38	31.67
Carbohydrates (%)	12.01	48.9	38.53	24.42
Dietary fiber (%)	5	33	7.51	-
Ash (%)	1	2.05	4.83	4.46
Total Solids (%)	32.05	95.04	-	-

Source: Asghar *et al.* (2023)

2.3.3 Bioactive Components

Soybeans are well-known for their rich composition of bioactive compounds, particularly isoflavones. These plant-based chemicals, classified as phytoestrogens due to their estrogen-like properties, belong to the flavone family and have been credited with numerous health benefits (Baiano *et al.,* 2009). The primary isoflavones in soybeans include daidzein, genistein, syringic acid, gallic acid, chlorogenic acid, and ferulic acid, which together form the main phenolic compounds. The concentration of these valuable components can vary significantly depending on the extraction process and production temperatures (Baiano *et al.,* 2009). A remarkable aspect of soybean processing is that a substantial portion of these isoflavones, about 12–30% is retained in okara, the by-product of soymilk production. Okara is particularly rich in glucosides (28.9%) and aglycones (15.4%), with smaller amounts of acetyl genistin (0.89%) (Jackson *et al.,* 2002). Interestingly, β-glucosidase, an enzyme present in some microbes, can convert isoflavone glucosides into aglycones, a form that is more easily absorbed by the human body (Izumi *et al.,* 2000). This bioconversion, which can be enhanced through fermentation, adds even more value to okara (Bhatia *et al.,* 2002).

Research has further highlighted the wealth of bioactive compounds in okara. Vong and Liu (2016) identified components such as malonyl glucosides (19.7%), isoflavone glucosides (10.3%), isoflavone aglycones (5.41%), acetyl glucosides (0.32%), saponins (0.10%), and phytic acid (0.5–1.2%). Additionally, Li *et al.* (2012) reported the presence of daidzein, glycitein, genistein, and total glucoside isoflavones in okara at concentrations of 1.79, 0.01, 1.76, and 3.56 µmol/g dry basis, respectively. The aglycone levels were slightly lower at 0.11 µmol/g dry basis, with individual contributions from daidzein (0.05 µmol/g), glycitein (0.02 µmol/g), and genistein (0.04 µmol/g). On a dry weight basis, Li *et al.* (2013) found that okara contains an impressive 355 mg/g of total isoflavones, including 54.1 mg/g of aglycones, 103.2 mg/g of isoflavone glucosides, 196.8 mg/g of malonyl glucosides, and 3.2 mg/g of acetyl glucosides. The health benefits of these isoflavones are profound. They have been linked to cancer prevention, heart health, reduced inflammation, and improved bone density. They also help lower cholesterol, reduce the risk of cardiovascular diseases, and alleviate menopausal symptoms. Additionally, isoflavones are associated with better cognitive function and reduced risks of certain cancers, including colon, breast, and prostate cancer (Li *et al*., 2013).

The secret behind these benefits lies in the potent antioxidant properties of isoflavones. Antioxidants combat free radicals (unstable molecules that can damage cells) thus protecting tissues from oxidative stress. Among soy isoflavones, genistein and daidzein stand out for their strong antioxidant activity. Both aglycone and glycoside forms are effective, with genistin showing specific protective effects against oxidative DNA damage and preventing low-density lipoprotein oxidation (Russo *et al.,* 2006). High-performance liquid chromatography (HPLC) studies confirm that okara is a rich source of isoflavones, including daidzin, glycitin, genistin, daidzein, glycitein, and genistein. According to Voss *et al.* (2018), genistin is the most abundant glucoside in okara, measured at 0.33 mg/g, followed by daidzin (0.25 mg/g), genistin (0.32 mg/g), and smaller amounts of daidzein and genistein (0.02 mg/g each) in dried okara.

2.3.4 Health Benefits of Okara

Globally, there are various closely related definitions of functional food. According to an EU document, functional food is defined as "a food that beneficially affects one or more target functions in the body beyond adequate nutritional effects in a way that is relevant to either an improved state of health and wellbeing and/or reduction of risk of disease. It is consumed as part of a normal food pattern and is not a pill, capsule, or dietary supplement" (John and Singla, 2021).

Functional food ingredients include soluble and insoluble dietary fiber (DF), carotenoids, phenolic acids, phytoestrogens, fatty acids, flavonoids, prebiotics, probiotics, soy protein, vitamins, and minerals. Extensive evidence suggests a strong connection between these ingredients and significant health benefits.

Okara, a by-product of soy milk production, is a rich source of isoflavones and other bioactive components (Kamble and Rani, 2020). Isoflavones, plant-based compounds with estrogen-like activity, are particularly notable for their role in reducing the risk of non-communicable diseases. They contribute to cancer prevention, osteoporosis protection, cardiovascular health, and reduced inflammation. Regular consumption of soy-based foods, including okara, has been linked to lowering blood cholesterol, preventing heart disease, reducing the risks of colon, breast, and prostate cancers, and improving cognitive function and menopausal symptoms (Jin *et al.,* 2021).

Dietary fiber in okara is another significant component, aiding in the prevention and management of Type 1 and Type 2 diabetes. It works by delaying carbohydrate absorption, increasing satiety, and reducing postprandial hyperglycemia (Quagliani and Felt-Gunderson, 2017). Fermented Okara offers even greater value as a functional food. Enriched with compounds like fucoxanthin and ecosapentaenoic acid (EPA), it serves as a nutraceutical with enhanced health benefits (Kim *et al.,* 2022). Incorporating okara into diets presents a practical and sustainable approach to improving health and reducing the risk of chronic diseases.

2.3.5 Nutritional Applications of Okara

Okara has been utilized as a dish or supper in China and Japan for numerous years. It is quite simple to add fiber and protein to food to help meet nutritional content claims. Okara can bind moisture and oil, making it an appealing low-price additive for increasing meat product production. The addition of okara (5%) in chocolate chip cookies increased its shelf life and decreased the syneresis during freezing and thawing. Okara fortified and supplement meat and bread can be used because it cannot change the flavor and texture of food (Mateos-Aparicio *et al.,* 2010). Ibrahim *et al.* (2022) reported that 2% and 3% okara fortification with probiotics (L. plantarum) and ice-cream significantly improved its chemical, nutritional, microbial, physical, and sensory properties. They called this food product synbiotic ice-cream because it enhances the growth of probiotics as well as nutritional composition. At the same time, Roslan *et al*. (2021) fortified yogurt with a probiotic (*L. Plantarum*) and okara (1%, 2%, and 3%). They also concluded that okara dietary fiber improves the probiotic count and chemical properties of yogurt with storage time.

Therefore, okara can be used in food industries as a value-added food and as a supplement food. Furthermore, freeze-dried okara has the highest swelling, lipid-binding, and water-holding abilities, usually accompanied by hot air drying and vacuum drying. Hot air-dried okara has the highest cation exchangeability, as compared to freeze-drying and vacuum-drying okara (Li *et al.,* 2011). Okara can be used in soy flour, wheat flour, and other components in food manufacturing to boost fiber and protein content. It has been used in the production of bread, pancakes, puffed noodle, food, confectionery, sausage, beverage, and nutritive flour. Production of bread with okara flour and wheat flour showed good nutritional and sensory properties. The crust color of bread changed significantly and improved the protein, fiber, and caloric contents (15 Kj/g). This bread could be used as a substitute food for diabetic patients (Wickramarathna & Arampath, 2003).

Rotem and Almog (2009) produced a protein-enriched premix powder incorporating okara for use in healthy foods. Dried milled okara (70 mesh) was combined with gluten in several proportions ranging from 3/1 to 12/1. The product comprised soy protein ranging from 10% to 30% and protein content ranging from 15% to 50%. Ostermann Porcel *et al.* (2017) described the gluten-free properties of okara flour or dried okara. Okara flour contains high contents of fiber, and protein.

Microwave treatment can alter the functional properties of okara. Asghar *et al.* (2022) studied the chemical properties of okara and then added 3% okara with probiotics in yogurt. In this experiment, okara used as a prebiotic and yogurt has antioxidant as well as probiotic property. They formed synbiotic yogurt by adding 3% okara with probiotic (*lactobacillus Rhamnosus*). The above studies clearly show that the addition of okara in any food item can increase the shelf life of the product as well as the nutritional and functional characteristics of the food product.

2.4 *Tuwo Shinkafa*

Tuwo shinkafa is a traditional dish widely consumed in northern Nigeria and other West African regions, particularly among Hausa-speaking communities (Aberoum and Deokunle, 2009). Made primarily from rice flour, it is a soft, sticky pudding-like food that pairs well with various soups such as *Miyan Kuka, Miyan Taushe*, and *Miyan Kubewa* ((Falade and Christopher, 2015). The dish holds a significant cultural and dietary value, often served at both everyday meals and special occasions. The preparation of *Tuwo shinkafa* involves a series of straightforward steps. First, the rice is sorted, washed, and cleaned to remove any impurities. Afterward, it is conditioned for a short period and dried in an oven at a temperature of 60°C for several hours to ensure the rice is moisture-free. Once dried, the rice is milled into a fine flour and then cooked into a smooth, thick consistency that can be easily molded and served alongside soups.

Despite its popularity, *Tuwo shinkafa* is often criticized for its low protein content. As a carbohydrate-dense dish, it lacks sufficient protein, which can contribute to malnutrition when consumed regularly without other sources of protein. The low nutritional density of *Tuwo shinkafa* has led to concerns, particularly in regions where it forms a significant portion of people's diets.One way to address this limitation and improve the nutritional value of *Tuwo shinkafa* is by incorporating okara flour. Okara, a byproduct of soy processing, is rich in protein, fiber, and other essential nutrients, making it an ideal supplement to boost the dish's nutritional profile. The addition of okara flour to rice flour for *Tuwo shinkafa* preparation can increase the protein content without altering the texture or taste significantly. This simple adjustment could provide a more balanced meal, benefiting the health and well-being of consumers, particularly in communities where protein deficiency is a concern.

Past research supports the benefits of incorporating okara flour into rice flour-based products, demonstrating improvements in their nutritional and functional properties. For example, a study found that cookies made from a mixture of okara (40%, 50%, and 60%) and rice flour performed better in terms of fiber, fat, protein, and carbohydrate content. The addition of okara flour not only enhanced the nutritional profile but also improved the overall quality of the product (Net *et al.*, 2023).Another study focused on gluten-free rolls made from okara flour at 0%, 5%, and 10% concentrations revealed that adding okara flour impacted the batter's viscoelastic properties. This study highlighted the potential of okara flour as a functional ingredient in gluten-free products (Tridtitanakiat *et al.,* 2023).

Additionally, the combination of okara flour and rice flour has been successfully used in the production of soy/rice cakes. An experiment found that the addition of okara pellets (rice flour and okara at 3:2 ratio) into rice-based cakes enhanced their texture, specific volume, and overall integrity, with a preference for cakes containing 70% okara. This shows that the inclusion of okara can improve the sensory and structural properties of rice-based food products (Xie *et al.*, 2008). These studies suggest that incorporating okara flour into *Tuwo shinkafa* could potentially enhance its nutritional content, particularly in terms of protein and fiber, while maintaining the traditional texture and flavor of the dish. The addition of okara flour could improve the overall quality and nutritional value of the product, making it a more nutritious alternative to traditional rice-based *Tuwo*.

Figure 2.3: *Tuwo shinkafa*

Source: (Olayiwola, 2022)

CHAPTER THREE

MATERIALS AND METHODS

3.1 Materials

Local rice (*ofada funfun/Oryza sativa L.)* and soybeans was purchased at Oja-oba market in Ilorin and carefully transported to the production site.

3.2 Methods

3.2.1 Production of Rice Flour

The method of Ogunlakin *et al.* (2014) was adopted with minor modifications. The local rice was manually sorted, washed, and cleaned. The cleaned rice was conditioned for 5 minutes and then oven-dried at 60°C for 4 hours. After drying, the rice was milled, cooled, and sieved through a 1 mm mesh to separate broken rice particles, yielding fine flour, which was stored in polyethylene bags.

3.2.2 Production of Okara Flour

The method of Villalobos *et al.* (2016) was adopted with minor modifications. Soybeans were thoroughly sorted to remove impurities and then soaked in water for 8–10 hours at ambient temperature. The soaked soybeans were ground using a local machine grinder, incorporating water to facilitate the grinding process. The water-to-bean ratio was maintained between 8:1 and 10:1. A thermal treatment was applied for 20 minutes at a temperature exceeding 90 ± 1 °C to reduce the activity of trypsin inhibitors and deactivate the lipoxygenase enzyme responsible for unpleasant taste. Soy okara was collected after extracting soymilk by filtering the slurry through a double layer of cheesecloth. The collected okara was oven-dried at 60 °C for 24 hours to reduce its moisture content. Once dried, the okara was ground into a fine flour, sieved using a mesh of approximately 0.2 mm, and stored in polyethylene bags for future research.

Rice grains
↓
Sorting, Washing and Cleaning
↓
Conditioning (5 min)
↓
Oven drying (60C for 4hrs)
↓
Milling
↓
Sieving
↓
Rice flour

Figure 3.1: Production of rice flour

Source: Ogunlakin *et al*. (2014)

Soybeans
↓
Sorting
↓
Soaking for 8-10hrs
↓
Wet milling
↓
Thermal treatment (90C for 20mins)
↓
Filtering
↓
Fresh Okara
↓
Oven drying(60C for 24hrs)
↓
Milling
↓
Dried Okara

Figure 3.2: Production of Okara flour

Source: Villalobos *et al.* (2016)

Table 3.1: Formulation for the production of *Tuwo shinkafa*

The experimental samples will incorporate okara flour at different concentrations;

Sample	Rice Flour (%)	Okara Flour (%)
TAA	100	0
TUB	95	5
TUC	90	10
TUD	85	15
TUE	80	20
TUF	75	25

3.2.3 Preparation of *Tuwo*

Rice *Tuwo* was prepared from each rice/Okara mix using a method described by Noah and Omoyeni (2020). The overall ratio of flour to water used in rice *Tuwo* preparation was 1:3.5 (w/v). A cold slurry of the flour was first prepared by mixing 20% of the desired quantity of rice flour (1.0 kg) with 25% of the desired quantity of water (3.5 liters). This was followed by bringing 60% of the water to a boil, after which the cold slurry was added to the boiling water while stirring vigorously with a wooden flat spoon to form a pap-like consistency. The remaining 80% of the rice flour was then gradually added to the boiling pap-like paste while continuously stirring to prevent lump formation and to ensure the formation of a homogeneous gel. The remaining 15% of the desired quantity of water was then added to the formed gel, covered, and allowed to cook for about 7 minutes. Afterward, the mixture was stirred vigorously to achieve a smooth gel. The final product obtained is called rice *Tuwo*.

Rice-okara mix

⬇

Mixing with water

⬇

Addition of the slurry to appropriate quantity of boiling water (with stirring)

⬇

Pap-like consistency

⬇

Addition of appropriate amont of flour to the Pap-like consistency (with vigorous stirring)

⬇

Gel-like consistency

⬇

Addition of small quantity of water

⬇

Cooking for 5-7 mins (covered without stirring)

⬇

Final stirring

⬇

Hot tuwo

Figure 3.3: Preparation of rice-okara *tuwo*

Source: Noah and Omoyeni (2020)

3.3 Determination of Proximate Composition of rice-okara flour blends

Proximate analysis was done according to the method of Association of Official Analytical Chemist's (2010).

3.3.1 Determination of Moisture Content

Stainless steel oven dishes were cleaned and dried in the oven (Memmert UH55 Germany) at 100°C for 1 hour to achieve a constant weight. They were cooled in a desiccator and then weighed. Two grams of sample was placed in each dish and dried in the oven at 100°C until constant weight was achieved. The dishes together with the samples were cooled in a desiccator and weighed.

% Moisture Content = $\frac{W_{2}-W_{3}}{W_{2}-W_{1}}$ Equation 1

Where W_1 = weight of dish

W_2 = weight of dish + sample before drying

W_3 = weight of dish + sample after drying

3.3.2 Determination of Crude Protein

Crude protein was determined using the Kjeldahl method (AOAC, 2010). Rice-okara flour (Two grams) was placed in the Kjeldahl flask. Anhydrous sodium sulphate (5g of Kjeldahl catalyst) was added to the flask. Concentrated H_2SO_4(25ml) was added with few boiling chips. The flask was heated in the fume chamber until the sample solution became clear. The sample solution was allowed to cool at room temperature, then transferred into a 250ml volumetric flask and made up to volume with distilled water. The distillation unit was cleaned, and the apparatus set up. Five millilitres of 2% boric acid solution with few drops of methyl red indicator was introduced into a distillate collector (100ml conical flask). The conical flask was placed under the condenser. Then 5ml of the sample digest was pipetted into the apparatus, and washed down with distilled water.

Five millilitres of 60% sodium hydroxide solution was added to the digest. The sample was heated until 100ml of distillate was collected in the receiving flask. The content of the receiving flask was titrated with 0.049M H_2SO_4(to a pink coloured end point. A blank with filter paper was subjected to the same procedure.

Calculation:

% Total Nitrogen = $\frac{\text{(titre−blank) x Normality of acid x } N_2}{Weight\ of\ sample}$ Equation 2

Nitrogen factor = 6.25

Crude protein = % total N x 6.25 Equation 3

3.3.3 Determination of Fat

The fat content was determined according to AOAC (2010) soxhlet extraction method. A 500ml capacity round bottom flask was filled with 300ml petroleum ether and fixed to the soxhlet extractor. Two grams of sample was placed in a labelled thimble. The extractor thimble was sealed with cotton wool. Heat was applied to reflux the apparatus for six hours. The thimble was removed with care. The petroleum ether was recovered for reuse. When the flask was free of ether it was removed and dried at 105°C for 1 hour in an oven. The flask was cooled in a desiccator and weighed.

Calculation:

% fat = $\frac{Weight\ of\ fat}{Weight\ of\ sample}$ x 100 Equation 4

3.3.4 Determination of Crude Fibre

Crude fibre was determined using the method in AOAC (2010). Rice-okara flour (three grams) was weighed into a 50ml beaker and fat was extracted with petroleum ether by stirring, settling and decanting three times. The extracted sample was air dried and transferred to a 600ml dried beaker. Then 200ml of 1.25% sulphuric acid and few drops of anti-foaming agent were added to the beaker. The beaker was placed on digestion apparatus with pre-adjusted hot plate and boiled for 30 minutes, rotating beaker periodically to keep solid from adhering on the sides of the beaker. At the end of 30 minutes period, the mixture was allowed to stand for one minute and then filtered through a Buchner funnel. Without breaking suction, the insoluble matter was washed with boiling water until it was free of the acid. The residue was washed back into the original flask by means of a wash bottle containing 200ml of 1.25% sodium hydroxide solution. It was again boiled briskly for 30 minutes with similar precautions as before.

After boiling for 30 minutes, it was allowed to stand for one minute and then filtered immediately under suction. The residue was washed with boiling water, followed by 1% hydrochloric acid and finally with boiling water until it was free of acid. It was washed Mice with alcohol and then with ether for three times. The residue was transferred into ash dish and dried at 100°c to a constant weight. Incineration to ash was done at 600°c for 30 minutes, cooled in a desiccator and weighed. The difference in weight between oven dry weight and the weight after incineration was taken as the fibre content of the sample This was expressed as a percentage weight of the original sample taken for analysis.

% Crude fibre

$$= \frac{Oven\ dried\ sample - Weight\ of\ sample\ after\ incineration}{Weight\ of\ sample\ taken} \text{ x } 100 \qquad \text{Equation 5}$$

3.3.5 Determination of Ash Content

Ash determination was carried out according to AOAC (2010) procedure. Rice-okara flour (Two grams) was placed in silica dish which had been ignited, cooled and weighed. The dish and sample were ignited first gently and then at 550°C in a muffle furnace for 3 hours, until a white or grey ash was obtained. The dish and content were cooled in a dessicator and weighed.

% Ash = $\frac{W_3 - W_1}{W_2 - W_1}$ X 100 Equation 6

Where W_1= weight of dish

W_2= weight of dish + sample before ashing

W_3 = weight of dish + sample after ashing

3.3.6 Determination of Carbohydrates

The Carbohydrate was determined by difference according to AOAC (2010), this was estimated by difference which is as follows

% Carbohydrate

= 100 - (% moisture + % fat + % ash + % protein + % crude fibre) Equation 7

3.4 Determination of the functional properties of the rice-okara flour blends.

3.4.1 Determination of bulk density

Bulk density was determined using the method described by Arise *et al.* (2023). A measuring cylinder (100 ml) was filled with flour to mark (100 ml), and the content weighed. The tapped bulk density was also obtained by following the same procedure but tapping for 50 times prior to weighing. Bulk density was calculated as the ratio of the bulk weight and the volume of the container (g/ml). The cylinder with the sample was weighed. The bulk density of the sample was determined by:

Bulk density (g/ml) = $\frac{W_1 - W_2}{V}$ Equation 8

Where W_1= weight of empty cylinder (g)

W_2= weight of cylinder + sample (g)

V= volume of cylinder occupied by the sample (ml)

3.4.2 Swelling capacity

This was determined using the method described by Adepeju et al. (2014). Rice-okara flour (Two grams) was weighed and poured into a measuring cylinder and the initial value was noted, 25ml of distilled water was added, the solution was vigorously shaken and left for 30 minutes, 1 hour and 2 hours. Then the final reading of the swollen sample was taken. The percentage of the Swelling index was calculated as;

$$\%\text{Swelling} = \frac{Initial\ reading}{Final\ reading} \times 100 \qquad \text{Equation 9}$$

3.4.3 Determination of Water Absorption Capacity

Water absorption capacity of the flour samples was determined using the method described by Arise et al. (2023). One gram of each sample was weighed into a 50-mL pre-weighed centrifuge tube, 10ml of distilled water was added. The dispersion was vortexed for 1 min, allowed to stand for 30 min and then centrifuged at 4,000 rpm for 30 min at room temperature. The supernatant was decanted, excess water in the upper phase was drained for 15 min, and the tube containing the residue was weighed again to determine the amount of water retained per gram of the sample. Water absorption capacity was calculated as;

$$\frac{\text{Weight of tube + residue after centrifuge)} - \text{Weight of empty tube}}{Weight\ of\ sample} \times 100 \qquad \text{Equation 10}$$

3.5 Determination of the Pasting Properties of the rice-okara flour blends

Pasting characteristics of the Rice-okara flour blends were determined using a Rapid Visco Analyser (Model RVA 3D; Newport Scientific, Narrabeen, NSW, Australia). Rice-okara flour (3 g) was weighed into a dried empty canister and 25ml of distilled water was added. The mixture was thoroughly stirred, and the canister was fitted into the RVA as recommended. The slurry was heated from 50 to 95°C with a holding time of 2 minutes followed by cooling to 50°C with 2 minutes holding time. The rate of heating and cooling was at a constant rate of 11.25°C min^{-1}. Peak viscosity, trough, breakdown, final viscosity, set back, peak time and pasting temperature were read from the pasting profile with the aid of Thermocline for Windows Software connected to a computer (Karim et al., 2015).

3.6 Determination of the Amino Acid Content of the rice-okara flour blends

Amino acid content was determined using Pico-Tag method (Bidlingmeyer et al. 1984). Briefly, the known (1.0 g) sample was hydrolyzed, evaporated in a rotary evaporator and loaded into Technicon Sequential Multi-Sample Amino Acid Analyzer (TSM-1) (Technicon Instruments Corporation, New York, USA). Ten micro liters (10 µL) of each hydrolysate was dispensed into the cartridge of the analyzer. The analyzer was separated and analyzed free acidic, neutral and basic amines, which will last for 76 h. Norleucine was employed as the internal standard. Ten micro liters (10 µL) of the standard solution mixture of the amino acid was also loaded into the analyzer. Values of both the standard and samples was recorded and printed out as chromatogram peaks by the chart recorder. Calculation from the peaks: The net height of each peak produced on the chromatogram (each representing amino acid) was measured. The half-height of each peak was located and the width of the peak at half-height will accurately be measured. Approximate area of each peak was then obtained by multiplying the height with the width of the half height. All measurement was in millimetre (mm). The norleucine equivalent (NE) for each amino acid in the standard mixture was calculated as:

$$NE= \frac{Area\ of\ neulocine\ peak}{Area\ of\ each\ amino\ acid\ in\ the\ standard\ mixture} \qquad \text{Equation 10}$$

3.7 Colour Measurement

The tristimulus color parameters (L*, a*, b*) of Rice-okara flour blends were determined using a Color Flex spectrophotometer (Model A60-1014593, USA), following standard calibration procedures. Measurements were taken in triplicate, with snapshots captured for each sample. The values were read directly from the device's digital display, and the average of the readings was calculated and recorded.

3.8 Sensory Evaluation of the Various Flour Blends

Sensory qualities of *Tuwo shinkafa* produced from rice-okara flour was evaluated using multiple comparison test (Akeem et al., 2023). The acceptability of the products in terms of colour, taste, mouldability, aroma, texture and overall acceptability was assessed by 50 untrained panelists comprising of students of University of Ilorin, based on a 9-point hedonic preference scale (1 = dislike extremely, 2 = dislike very much, 3 = dislike moderately, 4 = dislike slightly, 5 = neither like nor dislike, 6 = like slightly, 7 = like moderately, 8 = like very much and 9 = like extremely). Drinkable water will be provided for the panelists to rinse their mouths after evaluating each randomly presented coded sample.

3.9 Statistical Analysis

All experiments were conducted in triplicates except where it is stated otherwise. The data were subjected to one-way analysis of variance (ANOVA) and significant difference among means was determined by Duncan's multiple range test ($p < 0.05$) using SPSS 9 software version 15.0 (SPSS Inc., Chicago, IL)

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Functional Properties of rice-okara flour blends

Table 4.1 presents the functional properties of rice–okara flour blends. The parameters assessed include bulk density, water absorption capacity, and swelling capacity, which are essential in determining the suitability of flour blends for different food formulations, especially for products like baked goods, porridges, or weaning foods.

The bulk density of the samples ranged from 0.82 g/cm^3 in TUF to 0.95 g/cm^3 in TUB, with TUB having the highest bulk density and TUF the lowest (Table 2). The observed decrease in bulk density with increasing okara inclusion is likely due to the fibrous and porous nature of okara, which tends to trap more air and reduce the compactness of the blend. Bulk density is an important functional parameter that influences packaging requirements, material handling, and transport logistics. Lower bulk density is desirable in weaning food formulations, as it allows for the preparation of energy-dense meals with less volume. As reported by Mbata et al. (2009), lower bulk density facilitates easier digestion and higher nutrient delivery. Bulk density may also be influenced by the particle size, fiber content, and starch composition of the flours, as noted by Karuna et al. (1996).

The water absorption capacity (WAC) increased progressively with increasing levels of okara, from 1.13 g/g in TAA (0% okara) to 1.99 g/g in TUF (25% okara). This increase is attributed to the high fiber and protein content of okara, both of which contain hydrophilic groups capable of binding water effectively through hydrogen bonding. As reported by Nassar et al. (2008), flours with higher hydroxyl group concentrations in their fiber structure demonstrate greater water-binding capacity. This trend aligns with findings from Onweluzo and Nnabuchi (2009), who noted that fermentation and heat treatment of protein-rich flours enhance water absorption due to structural changes in starch and protein molecules. High WAC values are important in baked goods and porridges because they improve moisture retention, texture, and yield. The increase in WAC also reflects a stronger interaction between starch, protein, and fiber within the matrix, improving digestibility, as described by Iwe and Onalope (2001).

Swelling capacity showed a similar increasing trend, with TUF recording the highest value (0.89 mL/g) and TUB the lowest (0.39 mL/g). Swelling capacity is influenced by the water absorption index of starch granules and other hydrophilic components in the blend. The presence of okara, rich in both soluble and insoluble fibers as well as residual starch, likely contributes to higher swelling values, as reported by Ostermann-Porcel et al. (2017). Lower swelling in TUB may suggest limited starch-water interaction, possibly due to lower fiber or protein content. Higher swelling capacity in TUF indicates a greater ability of the flour matrix to expand and absorb water during heating, improving viscosity and mouthfeel key qualities for foods reconstituted with water or milk, such as infant cereals and instant blends, as noted by Loos et al. (1981).

However, the functional properties do not always follow a strictly linear trend with increasing okara content. This non-linear behavior arises from complex interactions between the flour components. Okara's fibrous and protein-rich matrix contains hydrophilic groups that strongly bind water, but physical factors such as particle size, porosity, and the nature of starch-protein-fiber interactions also play crucial roles, as reported by Ostermann-Porcel et al. (2017) and Li and Komarek (2017). The different swelling behaviors of soluble versus insoluble fibers, highlighted by Villanueva-Suarez et al. (2016), further contribute to variability. Processing methods and structural changes during blending affect functional properties, sometimes causing fluctuations beyond proportional increases, as shown by Nassar et al. (2008). Therefore, the observed trends reflect the complex physicochemical interplay within the flour matrix influenced by okara's unique composition.

Table 4.1: **Functional properties of rice-okara flour blends**

Sample	Bulk Density	Water Absorption Capacity	Swelling Capacity
TAA	0.90^{c}±0.00	1.13^{d}±0.00	0.69^{d}±0.00
TUB	0.95^{a}±0.00	1.28^{c}±0.00	0.39^{e}±0.00
TUC	0.93^{b}±0.00	1.45^{b}±0.00	0.69^{d}±0.00
TUD	0.90^{c}±0.00	1.46^{b}±0.00	0.74^{c}±0.00
TUE	0.86^{d}±0.00	1.95^{a}±0.00	0.79^{b}±0.00
TUF	0.82^{e}±0.00	1.99^{a}±0.00	0.89^{a}±0.00

Values are mean ± standard deviation. The mean values in a column with the same superscript are not significantly different from each other ($p \leq 0.05$)

KEY: TAA- 100% Rice flour
TUB- 95% rice flour + 5% okara flour
TUC- 90% rice flour + 10% okara flour
TUD- 85% rice flour + 15% okara flour
TUE- 80% rice flour +20% okara flour
TUF- 75% rice flour + 25% okara flour

4.2 Pasting Properties of rice–okara flour blends

The pasting characteristics of rice–okara flour blends are presented in Table 4.2. Pasting properties are critical in predicting the behaviour of starch-based ingredients during food processing, particularly under conditions of heating, cooling, and shearing. These parameters greatly influence texture, stability, and the final product quality of traditional starchy foods like *Tuwo shinkafa*. When flour is heated in water, starch granules gelatinize, swell, and eventually rupture, resulting in viscosity changes that can be measured using a Rapid Visco Analyzer (RVA). These variations offer insights into cooking behaviour, retrogradation tendencies, and the paste's resilience to thermal or mechanical stresses, as reported by Adebowale et al. (2005) and Yadav et al. (2012).

The peak viscosity, representing the highest viscosity reached during heating, ranged from 1018.50 RVU (TAA) to 3047.00 RVU (TUB). A high peak viscosity in TUB suggests efficient water absorption and starch swelling at 5% okara inclusion. Conversely, the low value in TAA indicates restricted swelling capacity, possibly due to limited hydration or structural interactions. This aligns with Maziya-Dixon et al. (2007), who noted that starches with low peak viscosities tend to form weaker gels. Increasing okara levels beyond a certain threshold may result in diminished starch availability for gelatinization due to competition from protein and fibre components, which disrupt granule expansion.

Trough viscosity, indicating the minimum viscosity during constant high-temperature holding, reflects the sample's ability to maintain integrity under shear. TUB recorded the highest value (2873.00 RVU), signifying strong paste stability, while TAA showed the lowest (502.50 RVU), again suggesting weaker paste structure. This pattern implies that low okara inclusion improves structural cohesion, while higher levels may weaken the starch network due to dilution and interaction with non-starch constituents.

Breakdown viscosity, the difference between peak and trough values, measures the degree of granule disintegration under heat and shear. TAA exhibited the highest breakdown (516.00 RVU), indicative of poor thermal stability, while TUE recorded the lowest (46.00 RVU), implying superior resistance to breakdown. According to Sanni et al. (2008), lower breakdown values suggest the formation of more stable pastes suitable for high-temperature cooking applications.

Final viscosity, which reflects viscosity upon cooling, ranged from 3651.00 RVU (TUF) to 5594.50 RVU (TUB). A higher final viscosity, as observed in TUB, suggests greater re-association of starch molecules (particularly amylose), resulting in firmer gels. This is crucial for products like *Tuwo shinkafa*, which require good mouldability and firmness after cooking. As reported by Julianti et al. (2017), high final viscosity is associated with better texture retention and reduced syneresis during storage.

Setback viscosity, calculated as the difference between final and trough viscosity, indicates the tendency of starch to retrograde upon cooling. It ranged from 1537.50 RVU (TUE) to 3904.50 RVU (TAA). A higher setback, as seen in TAA, may signal undesirable hardening and potential syneresis during storage, while lower values, like that of TUE, imply improved shelf stability and reheat quality. This agrees with the findings of Adebowale and Lawal (2003), who linked lower setback values to slower retrogradation rates.

Pasting temperature varied between 83.58°C (TUB) and 93.70°C (TAA). Higher pasting temperatures suggest that more energy is required to initiate gelatinization, possibly due to the presence of resistant starch structures or fibre-protein interactions inhibiting water penetration. As reported by Wireko-Manu et al. (2011), lower pasting temperatures are preferable in energyconscious processing systems, making TUB potentially more desirable in terms of cooking efficiency.

Lastly, peak time values, which ranged from 6.10 minutes (TUB) to 7.00 minutes (TAA, TUD, and TUF), reflect the time taken to reach peak viscosity. A shorter peak time, such as that of TUB, indicates quicker gelatinization a beneficial trait for quick-cooking food formulations, as emphasized by Adegunwa et al. (2014).

Table 4.2: **Pasting properties of rice-okara flour blends**

Sample	Peak Viscosity	Trough Viscosity	Breakdown Viscosity	Final Viscosity	Setback Viscosity	Peak Time	Pasting Temperature
TAA	$1018.50^{f}\pm84.15$	$502.50^{f}\pm48.79$	$516.00^{a}\pm35.36$	$4407.00^{d}\pm274.36$	$3904.50^{a}\pm225.57$	$7.00^{a}\pm0.00$	$93.70^{a}\pm1.27$
TUB	$3047.00^{a}\pm18.39$	$2873.00^{a}\pm18.39$	$174.00^{c}\pm0.00$	$5594.50^{a}\pm178.90$	$2721.50^{b}\pm160.51$	$6.10^{d}\pm0.24$	$83.58^{f}\pm1.73$
TUC	$2584.00^{b}\pm19.80$	$2507.00^{b}\pm2.83$	$77.00^{e}\pm22.63$	$4621.50^{b}\pm98.29$	$2114.50^{d}\pm101.12$	$6.33^{c}\pm0.19$	$84.38^{e}\pm0.60$
TUD	$2493.50^{c}\pm14.85$	$2295.50^{c}\pm13.44$	$198.00^{b}\pm28.28$	$4412.00^{c}\pm123.04$	$2116.50^{c}\pm109.60$	$7.00^{a}\pm0.00$	$86.83^{b}\pm0.53$
TUE	$2189.50^{d}\pm37.48$	$2143.50^{d}\pm23.34$	$46.00^{f}\pm14.14$	$3681.00^{e}\pm46.67$	$1537.50^{f}\pm70.00$	$6.77^{b}\pm0.05$	$84.78^{d}\pm0.04$
TUF	$2075.50^{e}\pm89.80$	$1922.50^{e}\pm94.05$	$153.00^{d}\pm4.24$	$3651.00^{f}\pm135.77$	$1728.50^{e}\pm41.72$	$7.00^{a}\pm0.00$	$86.38^{c}\pm0.04$

Values are mean ± standard deviation. The mean values in a column with the same superscript are not significantly different from each other ($p\leq0.05$)

KEY: TAA- 100% Rice flour

TUB- 95% rice flour + 5% okara flour

TUC- 90% rice flour + 10% okara flour

TUD- 85% rice flour + 15% okara flour

TUE- 80% rice flour +20% okara flour

TUF- 75% rice flour + 25% okara flour

4.3 Proximate Composition of rice-okara flour blends

The proximate analysis presented in Table 4.3 reveals a clear nutritional enhancement of rice flour blends with increasing substitution by okara. Notably, the inclusion of okara led to significant increases in crude protein, fiber, fat, and ash content, while the carbohydrate content declined progressively. This nutritional shift reflects the compositional richness of okara, a soybean by-product long utilized in East Asian diets for its high protein and dietary fiber content (Mateos-Aparicio et al., 2010).

Carbohydrate content decreased from 79.42% in the control sample (TAA, 100% rice flour) to 63.41% in the 25% okara blend (TUF), consistent with the fact that okara contains less digestible carbohydrates and more non-digestible fibers. This substitution not only lowers the glycemic load but also contributes to satiety and potential blood sugar regulation, as previously observed in fiber-enriched formulations (Mateos-Aparicio et al., 2010; Roslan et al., 2021). These results indicate the potential application of okara-enriched blends in diabetic-friendly or weight management diets.

The crude fiber content showed a marked increase from 1.31% in TAA to 3.44% in TUF. This aligns with findings by Roslan et al. (2021), who emphasized okara's substantial dietary fiber contribution, including soluble components like pectin and insoluble elements such as cellulose and hemicellulose. The nutritional relevance of this lies in its implications for gut health, cholesterol regulation, and reduced risk of metabolic disorders. Given the global shortfall in dietary fiber intake relative to WHO/FAO recommendations, the development of fiber-enriched staples through okara inclusion offers a practical and affordable intervention.

Protein content also increased substantially from 7.14% in the rice-only sample to 16.60% in the highest okara inclusion. This confirms prior work by Wickramarathna and Arampath (2003), who demonstrated that the incorporation of okara significantly boosts the protein quality of baked products. Since okara contains soy-derived proteins, which include all essential amino acids such as lysine (often limited in cereals), its addition to rice flour not only improves total protein quantity but also enhances the amino acid profile critical for populations relying on plant-based diets.

Crude fat content rose modestly from 0.58% to 2.03% across the blends. Though soybeans are naturally high in lipids, the defatting process during soymilk extraction limits the fat contribution of okara. Nonetheless, the increase aligns with the compositional trends observed by Mateos-Aparicio et al. (2010), who noted that okara retains residual lipids, contributing to functional and caloric balance in food systems.

Ash content, indicative of mineral presence, also increased significantly from 1.02% to 2.43%. This is in agreement with the work of Li et al. (2011), who reported that okara is a valuable source of essential minerals such as calcium, magnesium, iron, and potassium. These minerals play indispensable roles in enzymatic activities, bone development, and overall metabolic function, making okara-fortified products nutritionally superior to conventional cereal-based flours.

A slight but consistent increase in moisture content from 10.51% to 12.09% was also observed, likely due to okara's notable water-holding capacity, as previously described by Li et al. (2011). While this may raise concerns regarding shelf life, the values remain within acceptable limits for short-term storage.

Overall, these results reinforce existing literature on okara's nutritional benefits across diverse food matrices.

Table 4.3: **Proximate composition of rice-okara flour blends**

Sample	Moisture	Crude Fat	Ash	Crude Fiber	Crude Protein	Carbohydrates
TAA	$10.51^{e}\pm0.02$	$0.58^{e}\pm0.01$	$1.02^{e}\pm0.01$	$1.31^{f}\pm0.02$	$7.14^{f}\pm0.08$	$79.42^{a}\pm0.09$
TUB	$10.63^{d}\pm0.06$	$0.94^{d}\pm0.03$	$1.78^{d}\pm0.15$	$2.32^{e}\pm0.02$	$10.16^{e}\pm0.01$	$74.18^{b}\pm0.02$
TUC	$11.11^{c}\pm0.11$	$1.18^{c}\pm0.01$	$2.26^{c}\pm0.06$	$2.56^{d}\pm0.03$	$10.94^{d}\pm0.05$	$71.94^{c}\pm0.08$
TUD	$11.08^{c}\pm0.01$	$1.20^{c}\pm0.01$	$2.35^{b}\pm0.00$	$3.03^{c}\pm0.00$	$12.94^{c}\pm0.01$	$69.41^{d}\pm0.04$
TUE	$12.03^{b}\pm0.02$	$1.87^{b}\pm0.09$	$2.40^{a}\pm0.01$	$3.16^{b}\pm0.03$	$16.17^{b}\pm0.09$	$64.38^{e}\pm0.07$
TUF	$12.09^{a}\pm0.02$	$2.03^{a}\pm0.02$	$2.43^{a}\pm0.36$	$3.44^{a}\pm0.02$	$16.60^{a}\pm0.12$	$63.41^{f}\pm0.11$

Values are mean ± standard deviation. The mean values in a column with the same superscript are not significantly different from each other ($p\leq0.05$)

KEY: TAA- 100% Rice flour
TUB- 95% rice flour + 5% okara flour
TUC- 90% rice flour + 10% okara flour
TUD- 85% rice flour + 15% okara flour
TUE- 80% rice flour +20% okara flour
TUF- 75% rice flour + 25% okara flour

4.4 Amino Acid Composition of rice-flour blends

The amino acid composition of the rice–okara flour blends is shown in Table 4.4, comparing Sample TAA (100% rice flour) with Sample TUF (75% rice flour+25% okara flour). A closer examination reveals that most essential amino acids (EAAs) exhibited an increase in TUF relative to the control sample. Notably, leucine (8.58 g/100 g protein), isoleucine (4.03 g/100 g protein), valine (5.29 g/100 g protein), phenylalanine (4.97 g/100 g protein), methionine (3.79 g/100 g protein), and histidine (2.30 g/100 g protein) were all significantly higher in the TUF blend. This supports the use of okara as a complementary plant-based protein enhancer, aligning with findings from Momin et al. (2020), who observed that okara supplementation improved the essential amino acid profile of fortified flour blends.

Interestingly, the total essential amino acid (TEAA) content increased from 34.15 g/100 g protein in TAA to 36.54 g/100 g protein in TUF, further affirming okara's nutritional contribution. Similarly, the total non-essential amino acids (TNAA) rose from 41.35 to 44.58 g/100 g protein, with hydrophobic, hydrophilic, acidic, and basic amino acid subgroups also reflecting modest improvements.

However, a slight reduction in lysine content was observed in TUF (2.39 g/100 g protein) compared to TAA (2.44 g/100 g protein), which is contrary to expectations considering that okara, derived from soybeans, is typically rich in lysine. While this anomaly might appear contradictory, it can be scientifically justified. According to Zilic et al. (2006**),** high processing temperatures such as those used during micronisation and microwave toasting have been shown to significantly reduce lysine availability. Lysine is particularly vulnerable to heat-induced degradation via the Maillard reaction, which leads to the formation of nutritionally unavailable lysine–sugar complexes. Therefore, the thermal conditions employed during okara drying or flour preparation in this study may have contributed to partial lysine loss or reduced its bioavailability.

Overall, the improved amino acid spectrum in TUF confirms the potential of okara-fortified rice flour as a nutritionally enhanced substitute for conventional rice flour, particularly in addressing protein-energy malnutrition and improving the amino acid balance of flour-based products.

Table 4.4: **Amino acid properties of rice-okara flour blends**

Amino Acid	TAA (g/100g protein)	TUF (g/100g protein)
Essential Amino Acids(TEAA)		
Leucine	8.41	8.58
Lysine	2.44	2.39
Isoleucine	3.50	4.03
Histidine	2.08	2.30
Tryptophan	1.34	1.47
Valine	4.50	5.29
Methionine	3.42	3.79
Phenylalanine	4.35	4.97
Threonine	4.11	3.72
Total Essential Amino Acids (TEAA)	**34.15**	**36.54**
Non-Essential Amino Acids		
Tyrosine	3.10	3.44
Cysteine	1.63	1.88
Alanine	4.44	4.78
Glutamic acid	13.32	14.16
Glycine	3.37	3.52
Arginine	3.70	4.04
Aspartic acid	4.81	5.27
Serine	3.73	3.94
Proline	3.25	3.55
Total Non-Essential Amino Acids (TNAA)	**41.35**	**44.58**
Hydrophobic	28.37	29.70
Hydrophilic	15.94	16.50
Basic	8.22	8.73
Acidic	18.13	19.43

Values are mean ± standard deviation. The mean values in a column with the same superscript are not significantly different from each other ($p \leq 0.05$)

KEY: TAA- 100% Rice flour
TUF- 75% rice flour + 25% okara flour

4.5 Colour Attributes of rice-okara flour blends

Colour is a vital sensory and quality parameter in flour-based foods, as it influences first impressions, consumer acceptance, and even perceived freshness or nutritional value. The colour attributes of the rice–okara flour blends were measured using the CIELAB scale (L*, a*, and b*), and the results are presented in Table 4.5.

The lightness index (L*) displayed a non-linear pattern across blends. TUD exhibited the highest lightness (L* = 84.98), while TUC, despite interface, showed the lowest value (L* = 59.83). This contrasting behavior suggests that brightness is affected by more than okara concentration alone. As observed by Momin et al. (2020), moderate inclusion can maintain or even enhance L*, likely due to genistein's antioxidant bleaching effect reducing brown pigment formation. However, higher substitution may introduce pigments or encourage Maillard browning, darkening the blend. This complex interplay results in the irregular L* trend observed.

The a* values consistently increased with okara addition, indicating a shift toward red hues. TAA had the lowest a* (0.83), while TUC had the highest (4.00), correlating with increased pigmentation from okara or heightened Maillard browning. The rise in redness may also be due to phenolic compounds or flavonoids present in okara interacting during thermal processing.

Similarly, yellowness (b*) increased steadily from 7.88 in TAA to values over 15 in TUE, TUD, TUF reflecting enhanced cream or golden hues. Browning index studies on okara–wheat biscuits revealed significant increases in b* with higher okara inclusion, attributed to crude fibers and phytochemicals (Zinia et al., 2019). Such shifts are generally appealing in traditional foods like *Tuwo shinkafa*, which benefit from a warm, golden appearance.

Table 4.5: **Colour attributes of rice-okara flour blends**

SAMPLE	L^*	a^*	b^*
TAA	$75.21^d \pm 0.01$	$0.83^f \pm 0.02$	$7.88^f \pm 0.02$
TUB	$81.75^b \pm 0.02$	$1.84^e \pm 0.03$	$12.04^e \pm 0.04$
TUC	$59.83^f \pm 0.02$	$4.00^a \pm 0.02$	$12.13^d \pm 0.02$
TUD	$84.98^a \pm 0.01$	$2.28^d \pm 0.01$	$16.84^a \pm 0.02$
TUE	$80.48^c \pm 0.00$	$3.03^c \pm 0.00$	$16.28^b \pm 0.00$
TUF	$71.03^e \pm 0.12$	$3.49^b \pm 0.03$	$15.39^c \pm 0.17$

Values are mean ± standard deviation. The mean values in a column with the same superscript are not significantly different from each other ($p \leq 0.05$)

KEY: TAA- 100% Rice flour
TUB- 95% rice flour + 5% okara flour
TUC- 90% rice flour + 10% okara flour
TUD- 85% rice flour + 15% okara flour
TUE- 80% rice flour +20% okara flour
TUF- 75% rice flour + 25% okara flour

4.6 Sensory Attributes of rice-okara flour blends

Table 4.6 presents the results of the sensory evaluation of *Tuwo shinkafa* prepared from rice–okara flour blends. The sensory attributes assessed were appearance, texture, flavour, taste, aroma, and overall acceptability, using a 9-point hedonic scale. *Tuwo shinkafa* is a soft, dough-like product traditionally consumed with soups across northern Nigeria, and its quality depends largely on the smoothness, mouldability, and neutral flavour profile of the flour used. Introducing okara into rice flour for this purpose aimed to enhance its nutritional value while maintaining its sensory appeal.

Among all the samples, TAA (100% rice flour) had the highest scores in most parameters, including overall acceptability (7.26), taste (7.30), and flavour (6.78). This aligns with expectations, as rice flour alone produces a soft, bland *Tuwo* with high consumer familiarity. Interestingly, TUB (95:5 rice–okara blend) recorded the highest appearance score (7.36) and maintained strong ratings in texture (6.90) and aroma (6.48), suggesting that a small addition of okara did not negatively affect the visual or structural quality of the final product. In fact, its slight coarseness may have enhanced visual appeal and firmness.

TUC (90:10) also performed well, with particularly high ratings in texture (7.02) and overall acceptability (6.90), indicating that okara at this level contributes positively to the mouthfeel and dough-holding ability of *Tuwo shinkafa*. The sample TUD (85:15) followed closely, with overall acceptability at 6.82, showing that up to 15% okara inclusion still produced *Tuwo* that was considered pleasant and suitable for consumption.

However, higher okara levels in TUE (80:20) and TUF (75:25) led to a more noticeable decline in scores, especially in flavour, taste, and aroma. This may be attributed to the stronger presence of beany notes and the fibrous texture introduced by higher okara content, which could interfere with the smooth and mildly flavoured nature typically desired in *Tuwo shinkafa*. TUF, in particular, had the lowest scores in taste (5.58) and flavour (5.84), making it the least accepted variant despite its superior nutritional profile.

The results suggest that sensory parameters such as taste and flavour are more sensitive to okara addition than appearance and texture. This may be due to the interaction of okara's natural compounds with the neutral taste of rice. Nonetheless, samples up to 15% okara retained good consumer acceptance, showing promise for nutritional improvement without compromising the traditional eating experience of *Tuwo shinkafa*.

Table 4.6: **Mean sensory scores of *Tuwo shinkafa* made from rice-okara flour blends**

Sample	Appearance	Texture	Flavour	Taste	Aroma	Overall Acceptability
TAA	$7.04^b±1.44$	$6.44^e±1.37$	$6.78^a±0.91$	$7.30^a±0.91$	$6.56^a±1.42$	$7.26^a±1.03$
TUB	$7.36^a±1.01$	$6.90^b±1.31$	$6.02^d±1.35$	$5.74^d±1.76$	$6.48^b±1.54$	$6.82^c±0.98$
TUC	$6.88^c±1.24$	$7.02^a±1.32$	$6.32^b±1.49$	$6.44^b±1.97$	$6.38^c±1.61$	$6.90^b±0.95$
TUD	$7.08^b±1.07$	$7.00^a±1.01$	$6.16^c±1.46$	$6.40^b±1.63$	$6.54^a±1.43$	$6.82^c±1.24$
TUE	$6.84^c±1.30$	$6.68^c±1.49$	$6.02^d±1.29$	$6.14^c±1.69$	$6.36^c±1.26$	$6.38^d±1.50$
TUF	$6.32^e±1.66$	$6.50^d±1.67$	$5.84^e±2.09$	$5.58^e±2.17$	$5.86^d±1.54$	$6.12^e±1.80$

Values are mean ± standard deviation. The mean values in a column with the same superscript are not significantly different from each other ($p \leq 0.05$)

KEY: TAA- 100% Rice flour

TUB- 95% rice flour + 5% okara flour

TUC- 90% rice flour + 10% okara flour

TUD- 85% rice flour + 15% okara flour

TUE- 80% rice flour +20% okara flour

TUF- 75% rice flour + 25% okara flour

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This study successfully assessed the effects of okara flour addition on the physicochemical, functional, and sensory properties of *Tuwo shinkafa*. The findings revealed that the inclusion of okara flour at varying proportions significantly enhanced the nutritional quality of the final product, most notably increasing crude protein, dietary fiber, and fat content, while reducing carbohydrate levels. These improvements are largely due to the rich nutrient profile of okara, particularly its high-quality protein and fiber content.

Functionally, okara inclusion improved the water absorption capacity and swelling index of the flour blends, contributing to the structural integrity and mouthfeel of the prepared tuwo. Sensory evaluation identified the 10% okara substitution level (TUC) as the most preferred by panelists, suggesting this level as optimal for balancing nutrition and palatability.

Overall, this research demonstrates that okara can be effectively used as a functional ingredient to enhance the nutritional profile of traditional dishes like *Tuwo shinkafa*, while also promoting sustainability through the beneficial use of agro-industrial by-products.

5.2 Recommendations

Based on the outcomes of this study, the following recommendations are made:

- Optimal Inclusion Level**:** A 10% substitution of okara flour in rice flour is recommended for the production of *Tuwo shinkafa*, as it provides enhanced nutritional value without compromising sensory acceptability.

- Commercial Application**:** Food processors and small-scale industries should be encouraged to adopt okara fortification in staple foods as a cost-effective means of improving dietary protein and fiber intake.
- Drying Method Consideration**:** The method and temperature used in drying okara (e.g., oven drying at 60°C for 24 hours in this study) can significantly influence its nutritional quality, especially heat-sensitive nutrients such as certain amino acids and isoflavones. Alternative drying techniques like freeze-drying or vacuum drying should be explored in future studies to better preserve okara's bioactive compounds and enhance its nutritional contribution.
- Further Research**:** Studies should be conducted to evaluate the storage stability, microbial safety, and shelf-life of rice-okara flour blends.

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APPENDIX

SENSORY EVALUATION QUESTIONNAIRE

NAME: ____

DATE: ____

INSTRUCTION: You are presented with five (6) coded samples, please evaluate these samples of snacks for Appearance, color, flavour, taste, texture, aroma, and overall acceptability, then, indicate how much you like and dislike each sample using the scale below;

9………………………… like extremely

8………………………… like very much

7………………………… like moderately

6………………………… like slightly

5………………………… neither like nor dislike

4………………………… dislike slightly

3………………………… dislike moderately

2………………………… dislike very much

1………………………… dislike extremely

SAMPLES	APPEARANCE	COLOUR	TEXTURE	AROMA	TASTE	OVERALL ACCEPTABILITY
TAA						
TUB						
TUC						
TUD						
TUE						
TUF						

Appendix 1: *Tuwo* samples made from rice-okara flour blends