UNIVERSITY FOR DEVELOPMENT STUDIES

ASSESSMENT OF THE EFFECT OF PRETREATMENTS AND DRYING METHODS ON THE NUTRITIONAL QUALITY OF OKARA, AND OKARA-MAIZE COMPOSITED *TUO ZAAFI*

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BY

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[THESIS SUBMITTED TO THE DEPARTMENT OF AGRICULTURAL MECHANISATION AND IRRIGATION TECHNOLOGY, FACULTY OF AGRICULTURE, FOOD AND CONSUMER SCIENCES, UNIVERSITY FOR DEVELOPMENT STUDIES, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF PHILOSOPHY (MPhil) DEGREE IN POSTHARVEST TECHNOLOGY]

MAY, 2022

DECLARATION

Student

I hereby declare that this thesis is the result of my original work and that no part of it has been presented for another degree in this University or elsewhere:

Signature: ……….………………Date:……………………….

Name:………………………………………………………………….

Supervisor

I hereby declare that the preparation and presentation of the thesis was supervised following the guidelines on supervision of thesis laid down by the University for Development Studies.

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Name:…………………………………………………………………

ABSTRACT

Animal proteins are becoming largely expensive, hence the daily protein needs of low-income earners are unmet. This has triggered the need to explore rich but less expensive protein sources of plant origin such as okara, a soy residue to meet the protein needs of the consumer. One effective way of ensuring that consumers benefit from these less-expensive protein sources is their incorporation into frequently consumed diets. Therefore, this study sought to assess the effect of pretreatments (no pressing, 12 hours pressing and 24 hours pressing) and drying methods (sun drying, hot air drying and solar drying) on the nutritional quality of okara (soy residue) and maize-okara *tuo zaafi*. To accomplish the objective of the present study, the drying characteristics and proximate composition of the okara, the consumer acceptability and proximate composition of maize-okara *tuo zaafi* were determined using widely accepted scientific protocols. The study revealed that hot air drying (8.67±0.52 hours) presented the best drying condition of the okara samples, followed by the open sun (9.33±0.52 hours) and then the solar drying (14.33±1.51 hours) in that order. The drying methods had a significant ($p<0.001$) effect on the proximate composition of the okara samples. In contrast, the pretreatment had a significant effect on all the proximate parameters except the moisture and ash contents. However, the solar drying method resulted in the highest protein values compared to the open sun and the hot air drying methods. The unpressed okara samples dried using the solar drying method recorded the highest protein value (33.14 %) whiles, the 12 hours pressed samples dried using the hot air method recorded the lowest protein value (20.72 %). The acceptance of the sensory attributes of the *tuo zaafi* products decreased as the okara inclusion level increased. Hence, the *tuo zaafi* prepared using a 10 % okara inclusion level had similar sensory attributes as the maize-only *tuo zaafi*, while the other products (20 %, 30 % and 40 % okara inclusion level) were generally not accepted. The nutritional quality of the *tuo zaafi* products correspondingly increased with an increased inclusion level of the okara flour. Length of pressing and the drying techniques used greatly influenced the nutritional properties of the okara and okara-enriched *tuo zaafi*. Hence, for consumer acceptance of the okara-enriched TZ, 10 % okara flour inclusion level is recommended.

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DEDICATION

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Ghanaian traditional diets consist mainly of starchy root crops (cassava, yam), cereals (maize, rice, etc.), and plantain (Saleh *et al*., 2002). Starchy roots and cereals continue to supply nearly three-quarters of the dietary energy of the populace, and dietary diversity remains disturbingly low. They are often consumed with spicy soups or stews and meat and/or fish (Annor *et al*., 2016). Although the dietary content meets the energy needs of the populace, the proportion of proteins and lipids in the dietary energy supply is lower than recommended (FAO, 2009). The low protein level of the Ghanaian diet is linked with the expensiveness and unaffordability of animal protein sources, which limit their intake along with the starchy diets (Abakari *et al*., 2019). This largely explains the widespread protein deficiencies across the country and other developing nations (Adeyeye *et al*., 2017; Atlaw *et al*., 2020; Ghaly and Alkoaik, 2010). The over-reliance on animal protein sources whose unaffordability denies many the opportunity to meet their protein needs is because consumers do not seem to have alternatives.

Meanwhile, plant materials such as soy and its residues (okara) have been reported to be excellent sources of protein that could serve as an alternative and affordable protein sources to improve the protein content of traditional foods. Soymilk and soy curd (tofu) are the main soy products that have received some recognition as far as being a good source of protein is concerned. However, a greater portion of the soy, the residue, is often discarded after milk and tofu production, especially in Sub-Saharan Africa.

Soy residue, also known as okara, is the by-product gotten from soy curd (tofu) and soymilk and after production (Ullah *et al*., 2017). It has a rich stock of nutrients such as protein (25%), fat (20%), and dietary fibre (33%) when dried (Jankowiak, 2014; O'Toole, 1999). The protein content could be up to 40% on a dry basis (Ahlawat *et al*., 2017). Wet okara, however, contains about 8.08 % protein (Sengupta *et al*., 2012). Annual okara production of approximately 700,000 tons in Japan is mostly mainly used as fertilizer and domestic animal feed by small and medium scale companies after its production (O'Toole, 1999; Zinia *et al*., 2019). In some places, okara is added to soups and stews and used to prepare porridges and hot cereals (Francisco, 2013). It is also used as a dietary additive in certain baked foods, including biscuits and snacks to reduce caloric intake while increasing dietary fibre (O'Toole, 1999). However, okara in its fresh wet state deteriorates quickly resulting from its high moisture content and, hence cannot be stored for long (Ostermann-Porcel *et al*., 2017). Wet okara has a moisture content of about 80 % (Guimarães *et al*., 2018; Vong *et al*., 2016), and so to extend its shelf-life and encourage its consumption, drying is essential (Voss *et al*., 2018).

Food drying is intended to take out water from food and curtail microorganism growth and reproduction(Guimarães *et al*., 2018; Shi *et al*., 2021). Aside from extending food shelf life, drying can also save storage space and transportation costs (Jangam *et al*., 2011). Okara's shelf life has been reported to be extended by drying

(Azanza and Gascon, 2015). To increase protein intake, dried okara can be easily incorporated into a variety of diets and food products.

Tuo zaafi is one of Ghana's most popular and widely consumed diets. *Tuo zaafi*, known as TZ in Ghana, is a cereal-based thick paste staple prepared from cereals like maize, millet, and sorghum. *Tuo zaafi* is thus very high in starch and consumed with green vegetable soup made from okra, ayoyo, roselle, kenaf, bitter leaf, or sometimes freshly pounded cassava leaves with little or no protein source (FAO, 2016). Thus, incorporating okara into *tuo zaafi* will serve as an in-expensive way of improving the protein intake of consumers.

1.2 Problem Statement and Justification

Tuo zaafi is a locally preferred food that forms part of the everyday diet of some Ghanaians. As a culturally important meal (Ham, 2020), *tuo zaafi* upholds an important symbol of life in Northern Ghana. Okara is the insoluble residue left after milling the soybean and extracting water-soluble components for soy food products such as soymilk and bean curd known as tofu (Vong *et al*., 2016). Okara potrays a very perishable nature due to its high moisture content (80 %). However, its nutritional composition is markedly improved when dried and milled into flour. The food industry usually undervalues it and commonly used as feed for animals (Guimarães *et al*., 2018; Vong *et al*., 2016).

Wald *et al*., (2019) asserted that, a lot of Ghanaian dishes are largely starch-based foods that are deficient in protein. Gibson *et al*., (2015) conducted a study in both Ghana and the United Kingdom where the dietary macronutrient composition and food sources of native and Ghanaian adults in the diaspora were compared. It was found out that the native Ghanaian food had a lower protein content of 14 % as compared to that of Ghanaians in the UK (17 %). However, the situation in Northern Ghana, especially the Northern Region, is worse because most underprivileged households may not be able to afford protein from animal sources due to cost compared to plant sources (Laar *et al*., 2018). Since the most predominant food consumed by the natives in Northern region is *tuo zaafi* (FAO, 2016), okara considered as a by-product, could be dried and used to complement cereal in *tuo zaafi* preparation. The compositing of *tuo zaafi* flour with okara flour could enhance its protein quantity and quality to address low dietary intake of protein.

The perishable nature of okara poses a significant problem in terms of its disposal (Guimarães *et al*., 2018; O'Toole, 1999). Drying can extend the shelf-life of okara and save storage space (Jangam *et al*., 2011). Even though research has been conducted on okara's chemical composition, biological activity, and its prospects as a food supplement for humans and animals, there is limited study on its specific use as a protein enhancer (Ibidapo *et al*., 2019; Li and Lu, 2012; Rizzo and Baroni, 2018). Incorporating dried okara into the main staple, *tuo zaafi*, will benefit poor-income and protein-deficient households in the Northern region. Hence, this study seeks to assess the effect of pretreatments and drying methods on the nutritional quality of okara and okara-maize-composited *tuo zaafi*.

1.3 Objectives of the Study

1.3.1 Main Objective

To assess the effect of pretreatments (no pressing, 12 hours pressing and 24 hours pressing) and drying methods (sun, solar and hot air drying) on the nutritional quality of okara (soy residue) and maize-okara composited *tuo zaafi* in the Northern region of Ghana.

1.3.2 Specific Objectives

i. To determine the effect of different pretreatments and drying methods on drying characteristics of okara.

ii. To determine the effect of different pretreatments and drying methods on the proximate composition of okara.

iii. To evaluate the effect of okara flour inclusion levels on consumer acceptability of okara-enriched *tuo zaafi*.

iv. To determine the proximate composition of the control and okara-enriched *tuo zaafi.*

1.4 Significance of the Study

This is specifically to help address protein deficiency in Northern Ghana. Since okara is a relatively cheap protein-rich by-product of soybean, this will help increase their protein intake.

Generally, animal-based proteins are expensive, and because of this, most households are served foods with little or no meat at all. Therefore, incorporating okara in *tuo zaafi* will aid in improving the protein intake of consumers since dried okara has a protein content of about 24 – 40 % (Ahlawat *et al*., 2017; Francisco, 2013). Also, there will be value-added to okara since it is mainly discarded as waste (Li *et al*., 2019). The research conducted in this respect will further add to existing knowledge and literature on okara as basis for further research.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Soybean

Soybean is one of the leguminous crops that is gaining popularity in Ghana (Sanful and Darko, 2010). It is a member of the *Leguminosae* family, *Papilionoideae* subfamily, and *Phaseolae* tribe (Dupare *et al*., 2008; Sanful and Darko, 2010). Due to its usage as an edible oil and a major ingredient in animal feeds, such as chicken feed, it is becoming a more in-demand crop around the world (Santos, 2019). It is also a readily affordable source of high-quality protein, niacin, and phytochemicals (Hildebrand and Kito, 1984; Mark, 1995), making it a highly desired crop (Sanful and Darko, 2010). Soybean is used to make a variety of foods, including meats, baked goods, and infant food (Osthoff *et al*., 2010). Due to its nutritious nature, this bean is widely grown and consumed in various forms (Bhavya and Prakash, 2019).

2.2 Origin and Distribution

The wild parent of soybean, *Glycine ussuriensis*, now *Glycine soja*, was originally domesticated in China (Dupare *et al*., 2008). During the 7th century, soybeans in China were transported to neighboring nations by sea and land via trade activities. They were first brought to the United States of America and Brazil in the last century, when both countries became major soybean exporters (Bashan and De-Bashan, 2010).

2.3 World Soybean Production

Over the last four decades, soybean has been one of the tropical legumes that has shown steady increase in all production metrics such as growth and yield (Mutegi and Zingore, 2013) and remains the fastest growing crop for the past 15 years (Tamimie and Goldsmith, 2019). Medium to large-scale farms with high degrees of mechanization and capital-intensive methods of production produce the majority of the world's soybeans (Dunstan, 2016). The introduction of technological advancements in soybean cultivation and processing has resulted in significant economies of scale and has become a critical factor in the industry's structure on a national and global scale (Hartman and Murithi, 2019).

Between 1961 and 2007, global soybean production climbed by 4.6 percent every year, reaching an annual production average of 217.6 million tons between 2005 and 2007. Using an exponential smoothing model with a damped trend, worldwide soybean production is anticipated to rise by 2.2 percent per year, reaching a tonnage of 371.3 million by 2030 (Masuda *et al*., 2009). On the global front, the bulk of the soybean is stored, then shipped to large-scale industrial units for further processing into meal and oil (Dunstan, 2016). The USA is the leading exporter of soybean seed (about 44%), followed by Brazil (33%), and Argentine (11%). China is the largest importer, accounting for 38% of total imports (El-Shemy, 2011).

The global soybean market is dominated by a small group of countries, with the United States of America leading the pack in North America. They are followed by Brazil, and Argentina in South America, China and India in Asia, Italy, and France in Europe, South Africa and Zimbabwe in Africa, and Australia in Oceania (Islas-Rubio and Higuera-Ciapara, 2002). Soybean is the second-largest cash commodity and the first-largest value crop exported from the United States (Islas-Rubio and Higuera-Ciapara, 2002). It is a relatively new crop in Africa, and there are few high-yielding variety alternatives available, particularly for smallholder farmers. As a result, African smallholder farmers' soybean yields are lower than those in other soybean-producing regions of the world (Santos, 2019). African producers supply less than 1% of the world's soybeans (Cornelius and Goldsmith, 2019). As a result, soybean farming has been actively encouraged in Sub-Saharan Africa as a means of increasing rural household income (Martey *et al*., 2020). Within the last two decades, huge investments have been put in soybean research in Sub-Saharan Africa through the support of the Rockefeller Foundation which introduced farmers to soybean agronomy, value addition, and marketing in East African and Southern Africa (Mutegi and Zingore, 2013)

2.4 Cultivation

Soybeans grow best in temperate, tropical, and subtropical climates, according to Kolapo (2011) but really thrives in the tropics and subtropics throughout the year once water is available (Dunstan, 2016). Soybean farming and consumption may be traced back to China's early agricultural era (Agarwal and Dupare, 2013). Aside groundnut, most women in northern Ghana plant soybeans to fund both household consumption and investment expenses (Martey, 2018). Soybean is cultivated throughout East and South East Asia, where it is heavily depended on for food, animal feed, and medicine (Kolapo, 2011). For optimal growth, it requires well-drained fertile soil and 400 to 500 mm of rainfall per season (Dunstan, 2016). However, dry weather is essential for its ripening (Dunstan, 2016; Konno, 1979). Seeds of soybean that are not ripe are green and light yellow to brown when they are matured (El-Shemy, 2011). It has the shape of a crescent pod, about 3-7 cm long, with 1000 soybean seeds weighing 115-280 g. On the forage, the seeds are designed in a mass of 180-200 g (El-Shemy, 2011).

2.5 Soybean production in Ghana

Grain legumes remain a key source of revenue for farmers and nutritional protein for many Ghanaians (Aidoo *et al*., 2014). Soybean was brought to Ghana around 1910 and was utilized by farmers from Bimbila, Bawku, Nakpanduri, Karaga, and Tilli, all of which are located in Ghana's Northern Region (Plahar, 2006). Ghana harvests approximately 50,000 metric tons of soybeans annually (Dzogbefia *et al*., 2007). The legume was meant to be sold to England as a commercial crop while also providing food for Ghanaian farmers (Shurtleff and Aoyagi, 2007). Soybean production in Ghana is currently concentrated in the country's northern regions. Because smallholder farmers are unable to apply pricey fertilizers in sufficient quantities to assure better efficiency, output levels are typically low *(*Al-hassan *et al*., 2016). Even though it is still considered a relatively new crop, it has successfully infiltrated the menus of most Ghanaians, particularly infants and nursing mothers (Aidoo *et al*., 2014). Between 2002 and 2014, Ghana saw a 16 percent increase in soybean production, despite the fact that most farmers are limited by land and finances, limiting their production volume (Martey, 2018).

2.6 Utilization and importance of Soybean

Soybean remains a valuable commodity in the world for people whose nutrition is deficient in protein and calories (Keyser and Li, 1992). It has been used as meat, milk, cheese, bread, and oil by the Chinese (especially Manchuria), Japanese, Filipinos, and Indonesians over the years (Agarwal and Dupare, 2013). As a result of the high nutritious content of soybeans, they are ground into flour and used to make bread (Sanful and Darko, 2010).

Soymilk is rich, creamy milk made from the processing of soybeans (Afroz *et al*., 2016). It is cholesterol-free, gluten-free, and lactose-free, and it contains high-quality proteins and essential fatty acids. (Kuo *et al*., 2014). It is especially beneficial for youngsters who have milk (dairy) allergies or who require a high level of protein in their diet (Liu, 1997). Another product of soybean is soybean meal. Soybean meal is abundant and appealing as a poultry and fish feed ingredient due to its excellent protein quality and nutritional value (Agarwal and Dupare, 2013; Dunstan, 2016).

Soybeans are also used to make tofu (Li *et al*., 2012). Islas-Rubio and Higuera-Ciapara, (2002) reported that tofu is a cheese-like cottage product made into a cake, precipitated from soymilk by a calcium salt or, in some cases, by concentrated sea water and it serves as the most important of the non-fermented soybean foods in east Asia. Tofu is the basis of the Japanese diet, just as meat, milk, and egg products are in Western diets, and it is cholesterol-free and low in calories when compared to meat or cheese (Dunstan, 2016; Hymowitz and Newell, 1981; Islas-Rubio and Higuera-Ciapara, 2002). Soybean oil is a natural oil that is produced from whole soybeans and is the most often used oil. It is sold either as pure soybean oil or as a vegetable oil additive (Dunstan, 2016). Finally, dehulled soybeans can be cooked and fermented with a fungus called *Rhizopus oligosporus* to produce tempeh. Tempeh is favored by vegetarians all around the world, but its meat-like texture and mushroom-like flavor appeal to Western palates more (Aoki *et al*., 2003; Dunstan, 2016).

2.7 Health Benefits of Soybean

Soybean has numerous benefits both to mankind and livestock (Dogbe *et al*., 2013). They are of great interest because of their functional ingredients looking at it from the nutritional point of view due to its prospective health benefits of their protein contents and dietary fibre under hyperlipidaemic and atherogenic conditions (Mateos-Aparicio *et al*., 2010). Soy foods have grown in popularity around the world, and are a popular choice for many health-conscious persons due to their versatility, taste, nutritional value, environmental, and health benefits (Bolla, 2015). Soy also lowers cholesterol and saturated fat consumption, which results in a more desired level of blood cholesterol and, thus helps lower the risk of coronary heart disease (Venter, 1999). Likewise, in preventing heart diseases, and in maintaining a high cholesterol rate, soy can be used. It as well aids in curing diabetes (type 2), asthma, lung function, certain types of cancers (lung , endometrial, prostate, and thyroid) and helps do away with weak bone (osteoporosis) slowing progressing diseases of the kidney (Guimarães *et al*., 2018; Sanful and Darko, 2010). Furthermore, soy aids in the treatment of constipation and diarrhoea, as well as lowering protein levels in the urine of persons with kidney disease, enhancing memory and alleviating muscle stiffness. Most women use soy, which helps to prevent cancer of the breast, hot flashes for breast cancer, menopause symptoms, and premenstrual syndrome (PMS) (Bolla, 2015).

2.8 Protein in Soybean

The protein quality of food is dependent on the content, digestibility, bioavailability and utilisation of amino acids (Friedman and Brandon, 2001). Soy proteins are an example of a legume protein, which is the most important class of vegetable proteins, second only to animal proteins in terms of importance (Dzikunoo, Ayernor, and Saalia, 2015; Maziya-Dixon *et al*., 2017). Foods obtained from soybean are deemed to be highly nourishing and healthy based on their nutrient composition (Keyser and Li, 1992). They have all the necessary amino acids that humans require for growth and maintenance (Ostermann-porcel *et al*., 2017), as well as serving as vegetarian dietary solutions owing to their high level of protein and flexibility in meat production and substitutes of milk (Rizzo and Baroni, 2018). The percent protein in soybean is approximately 40% (Keyser and Li, 1992; Liu, 1997). Soybean protein is comparable to animal protein in terms of quality (Dunstan, 2016). Soybean seeds contain as high as 48 percent protein and are utilized in an array of human diets, such as infant formulae, flours, protein isolates and concentrates, and textured fibers (Friedman and Brandon, 2001). They are thus regarded good protein sources because of their phytoestrogen content, which aids in the reduction of cancer risk (Ostermann-porcel *et al*., 2017).

2.9 Protein deficiency and stunting among children

Protein deficiency is a common nutritional problem caused by inadequate protein levels in diets which adversely affects the body's ability to function properly (Golden, 1999) while stunting refers to underweight for age in children, frequently as a result of malnutrition, recurring illnesses, and/or a lack of social interaction

(Aly *et al*., 2014). Stunting starts in early childhood or before and usually persists to give rise to a small adult (Golden, 1994).

A large number of young children in developing countries suffer from several micronutrient deficiencies (Khor, 2003). Ghana is a victim of poverty and the consequences of it are devastating (Adjasi and Osei, 2007). The poverty rate is tremendously high in the Northern parts of the country as likened to the Southern parts. The Ghanaian diet is mainly composed of starchy food crops such as cassava, yam, maize, rice, and plantain. It is believed that many people in the Northern part of the country are impoverished and unable to afford high-protein foods, resulting in an unacceptable low protein intake (FAO, 2009). This thus renders these people highly protein-deficient even though proteins are essential components of human diets because of their role in the performance of specific bodily processes (Kinsella, 2009).

2.10 Okara

Okara is actually a Japanese word '*Gochuang*' which means 'honourable hull or shell'(Ahluwalia *et al*., 2018; Vidjannagni *et al*., 2021). It is also referred to as soy residue, an inexpensive soybean by-product, gotten from the processing of soybean curd (tofu) or soymilk and makes up 55% of the total soybean (Ibidapo *et al*., 2019). It is estimated that approximately 1200 g of the above by-product is gotten from 1000g of soybean during the processing of tofu (Li *et al*2012). Okara, when wet, contains about 75 to 80% of moisture, and it comes in a semi-solid form (Taruna and Jindal, 2002). On a dry matter basis, it has high nutritional content including

25% protein, 10 % fats, carbohydrates, 50% dietary fibre, and other nutrients (Ibidapo *et al*., 2019; Li *et al*., 2012).

Okara usually is white or yellowish (Noriham *et al*., 2016). It is referred to as *biji* in Korea and as *douzha* in China (Vong and Liu, 2016). The large usage of soybean in the production of soymilk and tofu leads to a worldwide increase in the quantities of okara being produced, as stated by Noriham *et al*. (2016). Okara is produced in huge quantities by soy product manufacturing companies in Asia due to soy products popularity in those countries (Vong *et al*., 2016). It even serves as a part of traditional foods for most Asians, especially for the people of China, Korea, and Japan (Noriham *et al*., 2016).

Okara easily and rapidly deteriorates owing to its high moisture content, leading to its underutilisation (Guimarães *et al*., 2018). It is usually fed to animals or thrown away due to its serious perishability problem (Li *et al*., 2012). Furthermore, because okara is produced in huge quantities each year, there is a significant problem with its disposal (Abdullah *et al*., 2019). There is therefore the need to explore the option of drying the okara right after production (Wachiraphansakul and Devahastin, 2007).

2.11 Extraction Methods of Okara

The production of okara worldwide is around 14 million tons and is mostly produced by Asian countries, like China and Japan (Mok *et al*., 2019). Japan produces about 800,000 tons of okara each year while China has about 2,800,000 tons annual production by the tofu industry (Kamble and Rani, 2020; Li *et al*., 2012; Ohno *et al*.,1993). Approximately 16 billion yen is used in disposing off okara in

Japan every year (Li *et al*., 2013). There are two different methods through which okara is gotten (Eze, 2019; Liu, 1997): the Chinese and Japanese methods.

In the former, soybeans are soaked, washed and later milled. To obtain the residue, the slurry is placed in a cheese cloth and squeezed to drain away the milk (Kamble and Rani, 2020; Liu, 1997; O'Toole, 1999). With the Japanese process, the soybeans are as well soaked and rinsed. The rehydrated soybeans are then cooked and ground to obtain the okara (Kamble and Rani, 2020; O'Toole, 1999). The Chinese also refer to okara as soybean residue, bean curd residue, *douzha* or *tofuzha* (Li *et al*., 2012). Yuan and Chang, (2007) reported that in the process of grinding soybeans, hydroperoxide and lipoxygenase of the beans come into contact with the unsaturated fatty acids, generally linoleic acid, which leads to the formation of aromatic compounds including hexyl, alcohols and nonylaldehydes. These odourants with low levels of detection account for the off-flavours in raw soymilk. Yuan and Chang, (2007) further indicated that the reasons behind the off-flavours are the denaturation of enzymes usually above 80℃ as well and grinding prior to the boiling of the filtrate leading to the production of okara with more 'beany' and 'green' character as in the case of the Chinese method. This makes okara gotten from the Japanese method of soymilk production more appetizing than the Chinese okara. Also, Japanese okara is more probable to contain a lesser amount of trypsin and hence easily incorporated in processing and cooking (Stanojevic *et al*., 2014).

2.12 Physicochemical Properties of Okara

The components of okara are dependent on the type of soybean, soy milk processing method, and the number of water-soluble components extracted from milled soybean (Li *et al*., 2012; Vong and Liu, 2016). This residue is made up of protein, oil, dietary fibre, monosaccharides, and oligosaccharides. Okara is very high in cellulose, which accounts for roughly half of the dry weight in soybean while containing very few calories. Okara is a high-quality dietary fiber that is not digestible in the small intestine but in the large intestine, can be fermented by microbes (Li *et al*., 2013). According to Suruga *et al.* (2011), on a dry basis, okara contains approximately 25% protein, 20% fat, and 33% dietary fibre. It also contains nearly a third of the isoflavones found in soybean. Other soy components found in okara include lignans, phytosterols, coumestans, saponins, and phytates (Abdullah *et al*., 2019). In addition, okara contains trace amounts of starch and sugars, as well as significant amounts of the B vitamin group and potassium (Ahlawat *et al*., 2017). This peculiar composition of okara makes it a potential source as a functional ingredient in the food industry.

2.12.1 Moisture Content

Water is a principal component in many foods. The tolerable levels of moisture differ in different foods. Any change in the moisture content could have severe effects on the product quality (Park and Bell, 2004). Soybean contains 8% moisture on average (Kakade *et al*., 2019). Okara; the by-product of soymilk processing (Zinia *et al*., 2019) has a high moisture content of about 70%-80% when wet and most of the water is bound to fibre which results in a clumpy appearance and makes its structure resemble that of wet sawdust (Vong and Liu, 2016). The moisture content of okara on a dry matter basis reportedly ranges between 8.4-22.9% (Rahman *et al*.,2021). Wet okara is considered a depreciated product because of its high moisture content, but its storage volume is low and has greater stability for storage when its moisture content is reduced after dying (Kamble and Rani, 2020). Also, when okara is wet and its moisture is high, it deteriorates very fast and hence has limited application in making different products. Okara is useful when dried to desirable moisture content, hence can be used for further applications in food processing (Guimarães *et al*., 2018). (Hassane *et al*., 2017; Mbaeyi-Nwaoha and Uchendu, 2016) emphasized that the moisture content of food, for example, flour, has a significant impact on its nutrient density and shelf-life. According to Kolawole *et al*., (2010), food substances with high moisture content will allow microorganisms to grow at a rapid rate, whereas 15 percent moisture content is said to promote enzymatic reactions and interactions of other constituents of the dried product, resulting in vitamin loss. Depending on the amount of moisture in a food product, the method used to determine moisture may measure more or less of it. Typically, the motive for the use of official methods with clearly defined procedures (Mauer and Bradley, 2017).

2.12.2 Protein

Proteins are an essential component of food for both human and animal survival, and their role in nutrition is to provide adequate amounts of essential amino acids (Wu *et al*., 2013). Okara contains approximately 25% protein (dry basis), has a high nutritive quality, and a superior protein efficiency ratio, implying that it is a potential source of inexpensive vegetable protein for consumption (Li *et al*., 2012). In a study conducted by Ma *et al*., (1996) protein was extracted from okara for 30 minutes at pH 9.0 and temperature 80°C, respectively, yielding a protein recovery rate of 53%. Isoelectric precipitation at pH 4.5 was used to isolate the extracted protein, and the dried, defatted protein isolates (prepared at 25 and 80°C) contained upwards of 80% protein constituents. The protein isolates in the okara were seen to have critical amino acid profiles not so different to that of how FAO scores, as well as high *in vitro* protein digestibility, with methionine and cysteine serving as the limiting amino acids. Further study with polyacrylamide gel electrophoresis in sodium dodecyl sulphate revealed that okara protein isolates possessed a huge amount of high molecular weight components signifying protein aggregation. Data from differential scanning calorimetry and hydrophobicity suggested that the okara products had extensive protein unfolding. However, at both acidic and alkaline pH, okara protein isolates had lower solubility than commercial soy protein isolates, possibly due to protein aggregation. Protein is generally removed from samples using proteases. An example is a papain (Cui, 2005). In the extraction process of crude protein, the Kjeldahl method is mostly used. It involves three different steps namely; digestion, distillation, and titration. Traditionally, digestion is performed in Kjeldahl flasks with capacities ranging from 500 to 800 ml and heated by gas or electricity. For distillation, water and alkali are first added to the digested sample and it is followed by the heating of the flask to distil >150 ml distillate. The distilled ammonia is captured in standardized acid, before being back titrated with standardized NaOH (Thiex *et al*., 2002).

2.12.3 Fibre

Dietary fibre is the seventh most important nutrient for organisms, and it is classified as either soluble or insoluble dietary fibre based on solubility (Vong and

Liu, 2016). Insoluble dietary fibre primarily increases faecal volume and is beneficial for digestive tract detoxification. It is also less susceptible to colonic fermentation than soluble dietary fibre. The soluble counterpart, on the other hand, can be used to lower blood pressure, avert gastrointestinal issues, and protect against cancers such as cancer of the breast, colourectal cancer, as well as prostatic cancer (Huang *et al*., 2015).

Dietary fibre is a group of compounds composed of plant carbohydrate polymers, both oligosaccharides, and polysaccharides, such as cellulose, hemicelluloses, pectin substances, gums, resistant starch, and inulin, which could be linked with lignin and other non-carbohydrate components (e.g., polyphenols, waxes, saponins, cutin, phytates, resistant protein). Dietary fibre is not broken down quickly by human digestive enzymes. It can be added to other foods to improve their textural properties (Chen *et al*., 2014; Elleuch *et al*., 2011).

Okara is very high in fibre, making it a potential nutritious food ingredient (Aguado, 2010). Its high content of dietary fibre (50-60%) make it of great health benefit potential as noted above. Thus, okara's fibre content provides food formulators with an additional natural unique ingredient for the market (Schved and Hassidov, 2010).

2.12.4 Ash Content

The inorganic residue left after the ignition or complete oxidation of organic matter in foodstuffs is referred to as ash (Marshall, 2010). Ash mainly consists of the minerals present in the food product (Ismail, 2017). Per Mbaeyi-Nwaoha and Uchendu, (2016); Vong and Liu, (2016); Zinia *et al*., (2019), the ash content present in okara is around 3.0 - 4.5g/100g (dry basis). Vital *et al*. (2018) identified significant proportions of phosphorus, potassium, calcium, zinc, magnesium, iron, and copper in okara indicating the potential of okara in combating micronutrient deficiency within the populace. Studies have demonstrated that pretreatment methods such as fermentation improve the mineral composition of okara (Rahman *et al*., 2021) making the raw material more nutritionally valuable for food fortification (Stanojevic *et al*., 2014). Micronutrient deficiency still exists within the populace leading to conditions such as anaemia, goitre, (alopecia), diarrhoea, etc. (Hendricks *et al*., 2008). This has compelled researchers and governments to take a keen interest in food safety and food quality (Afify *et al*., 2017). Ash content of food is necessary for nutritional labelling.

2.12.5 Crude Fat

The fat present in food does not only contribute to flavour but also influences the intensity, duration, and balance of the other flavours present (Lucca and Tepper, 1994). Soybean is composed of about 22% fat and has been consumed mostly as cooking oil (Guimarães *et al*., 2018). Okara contains about 8.3-10.9% of fat (g/100 g dry matter (Li *et al*., 2012; Vong and Liu, 2016)**.** The major fat sources in okara are polyunsaturated fatty acids together with lesser amounts of monosaturated fatty acids (Feng *et al*., 2021).

Fats impart a wide range of sensory qualities to foods, including desirable appearance, flavor, aroma, texture, and mouthfeel (Lucca and Tepper, 1994).

2.12.6 Carbohydrates

Carbohydrates are an essential nutrient in foods and raw materials. They can occur naturally or be added to food products to provide nutrients while also improving consistency and quality (Cui, 2005). Cui, (2005) again reported that the most abundant naturally occurring carbohydrate present in food products is starch, followed by pectin, hemicellulose, and cell wall materials. Soybean contains approximately 23% carbohydrates (Kakade *et al*., 2019). Okara when wet contains about 8% carbohydrate (Lin *et al*., 2020) but on a dry weight basis, it contains approximately 50% carbohydrates which consist of cellulose, hemicellulose, and pectin (Choi *et al*., 2015; Vong and Liu, 2016). The total carbohydrates basis for okara is soluble sugars (3.9-6.6%), starch (0.5-1.8 %), and total dietary fibre (31.8-54.3%), which is dependent on the methods of processing and soybean varieties used (Mateos-Aparicio *et al*., 2010; Surel and Couplet, 2005)**.** The amount of free carbohydrates such as glucose, galactose, sucrose, arabinose, stachyose, and raffinose is low at 4-5% in okara (Redondo-Cuenca *et al*., 2008). The 1.4% stachyose and raffinose contained in the residue may either cause flatulence or bloat in certain individuals (Vong and Liu, 2016). Vong and Liu, (2016) again asserted that cell wall monomers of polysaccharides of okara are primarily arabinose, xylose, galacturonic acid, fucose, glucose, and galactose, with a trace of rhamnose and mannose. The main factor limiting efficient microbial growth in okara is a lack of fermentable carbohydrates (Mateos-Aparicio *et al*., 2010).

2.13 Applications of Okara

Okara is an extensively known source of food in both China and Japan. This residue is not difficult to be added to a product to aid in achieving its claim of being highly rich in nutrients such as fibre and protein (Li *et al*., 2012). Similarly, at an optimum 5 percent level, it improves shelf life in chocolate chip cookies and prevents syneresis during freezing and thawing in cheese ravioli filling (Mateos-Aparicio *et al*., 2010). Okara has a bland flavour and permits high levels of usage without negatively affecting the flavour or texture profiles of meat and bakery products (Li *et al*., 2012). Okara is known for its moisture and oil-binding properties making it a suitable and affordable ingredient for increasing yield in meat products (Mateos-Aparicio *et al*., 2010). Li *et al*., (2012) found no differences in milk yield, milk fat percentage, fine feed consumption, or daily gain when half soybean was replaced with okara for 30 days in dairy cattle and yellow cattle. Okara, because it is less expensive than soybean meal, can be used as a partial replacement for soybean meal during feeding. Guimarães *et al*., (2018) investigated the application of okara on the development of paté flavourings to yield a product with good acceptability and nutritional quality. The results showed enhanced sensory properties of the product.

Okara can be used in baked foods, such as gluten-free bakery products, cookies and nutritional bars (Abdullah *et al*., 2019). It serves as an appropriate dietary additive in cookies and snacks due to its reduced calories and increased dietary fibre (Ahlawat *et al*., 2017; O'Toole, 1999). The residue can also be added to soups and stews, porridges and hot cereals (Francisco, 2013). Furthermore, it can be used as fermentation substrate for the production of ethanol and methane (Mbaeyi-Nwaoha and Uchendu, 2016). The protein in okara can be used as a nitrogen source for fertilizing soils for crop production. The fibre content improves the texture of the soil and likewise be added to other composting ingredients, adding organic nutrients and nitrogen to the soil. Additionally, it can be dried and used in the feed of animals (Francisco, 2013). It therefore possesses significant characteristics that make it a viable substitute for incorporation into the production of pate (a soft mixture of vegetables transformed into a paste to which various flavorings are added) (Guimarães *et al*., 2018).

2.14 Nutritional and Health benefits of Okara

It has been stated that the bioactive components of okara can protect the body from hypocholesterolaemia, type 2 diabetes, and hypolipidemia through reduced glycaemic after consumption (Kamble *et al*., 2019). Okara's high-quality protein fraction is water-retaining and emulsifying, and it contains an anti-hypertension peptide (O'Toole, 1999). The consumption of large amounts of soluble fibre and a high protein diet by diabetics can assist in regulating sugar levels in the blood by reducing the rate at which carbohydrate is being absorbed in the intestine. The high levels of fibre and protein in okara make it a perfect diet for diabetics (Li *et al*., 2012). It is also known for its ability to help prevent obesity and fat accumulation in the liver (Quintana *et al*2017). Okara also contains isoflavonoids that have positive health effects like reducing the risk of certain cancers dependent on hormones, cardiovascular diseases, and osteoporosis owing to its ability to bind the oestrogen receptor (Ahlawat *et al*., 2017). A study conducted by Li *et al*,. (2012) on male golden Syrian hamsters fed high-fat diets supplemented with okara for three weeks revealed that total lipids, triglycerides, total and esterified cholesterol concentrations in the liver were lowered; thus, showing the great potential of okara in the prevention of hyperlipidaemia.

The high dietary fibre, protein, considerable isoflavone, and mineral elements contained in okara make it possess high nutritional value and a potential prebiotic effect (Li *et al*., 2012). It could be suitable, therefore, as a functional ingredient with health-promoting attributes (Ruperez *et al*., 2008).

The presence of rich protein and dietary fibre in okara plays an important role in many physiological processes in the prevention of various diseases. The specific proteins in okara are considered high quality, because they contain all the essential amino acids, and can lower triglycerides and cholesterol levels such as low-density lipoprotein and very-low-density lipoprotein (Ostermann-porcel *et al*., 2018). Okara has high nutritional value as well as exceptional functional properties such as solubility of protein, water retention capacity, foaming, emulsification, and binding properties that make it an excellent addition to food products (Ahlawat *et al*., 2017).

2.15 Preservation of Okara

After soymilk extraction, the okara left is wet to somewhat humid depending on the efficiency of the water phase removal from the draff (O'Toole, 1999). Okara is highly perishable due to its high moisture content requiring the need for its preservation (Guimarães *et al*., 2018). According to a study by Schved and Hassidov (2010), okara is of limited use as a food ingredient because it deteriorates quickly. Kato *et al*., (1986) used lactic acid bacteria as starter cultures to prevent microbiological putrefaction of okara. Dried lactic acid bacteria and yoghurt were added to okara with or without 1% glucose and were then exposed to aerobic and anaerobic conditions. It was noticed that deterioration occurred quickly under aerobic conditions. According to O'Toole (1999), okara was also fermented due to lactic acid bacteria presence when it was packaged in a polyethylene film bag or a screw-cap bottle. Its pH value was also reduced to 4.2, which inhibited the growth of spoilage bacteria for at least four days at 37°C. One other method of preservation of okara is drying immediately after production.

2.16 Drying of Okara

Drying processes are commonly used to preserve foods by reducing the moisture content and lowering the level of deterioration (Guimarães *et al*., 2018; Murthy, 2009). To avoid the growth and reproduction of micro-organisms in food, drying is necessary (Shi *et al*., 2021). Drying does not only extend food shelf life but also saves storage space and cost of transportation (Shi *et al*., 2021). Okara can be dried to aid in removing undesirable anti-nutritional factors (Wachiraphansakul and Devahastin, 2007). One vital aspect to note when drying okara is to preserve the protein quality because the conditions of drying can affect it (Grizotto and Aguirre, 2011; Sengupta *et al*., 2012). Below are some of the methods through which okara can be dried.

2.16.1 Open-Sun Drying

It is an inexpensive and simple method of drying which depends on sun radiations for its operation (Jain and Pathare, 2007; Ojutiku *et al*., 2009). Open-sun drying has been used over the years to dry food products; vegetables, fish, fruits, milk products, etc., due to the high cost of fossil fuels, etc.(Sahdev, 2014). Sahdev (2014) again reported that in this method of drying, the product is spread on the ground in the open, where heat is transferred from the surrounding air and from the sun to the surface of the product. Open-sun drying is not reliable because of the uncertainty of the weather, high cost of labour, infestation of the product by insects, dust entering the product being dried. This method of drying requires long periods for drying and may have adverse effects on the product quality as a result of product contamination by dust or insects (Amer *et al*., 2010; Andritsos *et al*., 2003).

2.16.2 Solar drying

Solar drying is one of the widely used methods of preservation owing to its numerous benefits (Barroca and Guine, 2017; Ukegbu and Okereke, 2013). It serves as an improved method of sun drying as it reduces or eliminates some of the drawbacks associated with open sun drying (Jain and Pathare, 2007; Ojutiku, Kolo, and Mohammed, 2009). In solar drying, a structure usually very simple and enclosed traps heat inside it (Ojutiku, Kolo, and Mohammed, 2009) and helps remove moisture from the products by the solar heated air (Kumar *et al*., 2016). Amer *et al*. (2010) conducted a study that found that systems that are closed prevent food products from being exposed to rays of the sun, contamination by dust, rain, insects, and rodents as well as the deterioration of the nutritional properties of the product.

Ukegbu and Okereke (2013) studied the effect of solar and sun drying on the nutrient composition of three species of vegetables and found out that the solar-dried vegetables contained more carbohydrate, protein, fat, ash, and fibre than sun-dried vegetables. Ojutiku *et al*. (2009) in their study proved that the solar drying was more efficient and reliable as the products were of good quality and had higher nutritional value and hygienic condition than that of the sun-drying method. Similarly, Abraha *et al*. (2017) also found that the solar-dried fish products were superior to that of the open sun-dried fish products. Hussein *et al*. (2018) revealed that the solar drying method produced significantly better proximate composition of okra than open-sun drying. Similar findings were reported by Singh *et al*. (2018) when they compared open sun drying and solar drying of *Phyllanthus emblica* (Anvla), Aloe Vera, *Aegle marmelos* (Bel) and leaves of *Azadirachta indica* (Neem), and *Psidium guajava* (Guava).

2.16.3 Hot air Drying

Hot air drying is a popular method of food preservation (Guiné, 2018). This type of drying of food products has an indispensable role in various industrial applications. It entails exposing a product to continuous removal of moisture. Hot air drying is a complex concept because of the various mechanisms of heat, mass, water, and energy transport processes (Onwude, *et al*., 2016). Also, because of the high availability of moisture saturation capacity of hot air drying, air is the most commonly used drying agent (Dobre, *et al*., 2016). The techniques for drying foods that use hot air are extremely versatile and important. An example is drying with trays in chambers or in tunnels equipped with conveyor belts in rotating drum dryers or in fluidized bed-type dryers (Guiné, 2018).

Ran *et al*. (2018) produced powdered chicken using hot air drying, hot air-assisted radio frequency drying and spray drying methods. The study concluded that hot air drying is the best technique for preparing chicken powder. Likewise, Elmas *et al*.

(2019) found that the moisture content and water activity of jujube values decreased with increasing temperature (60,70 and 80℃). The study saw that as the temperature increased, the total phenolic content of the jujube powder decreased. Montoya-Ballesteros *et al*. (2017) also performed a research on the effects of open sun drying and hot air drying methods on capsaisin, capsanthin and ascorbic acid content in chiltepin, concluded that hot air drying method is better than open sun drying method since it retained higher content of capsanthin and ascorbic acid compounds in chiltepin. However, contrary to the above studies where the researchers had satisfactory results from using hot air dryers below are some studies that gave opposite outcomes.

Balzarini *et al*. (2018) investigated the effect of drying conditions on the retention quality of dried chicory roots using vacuum dryer and hot air dryer and found that the samples dried with vacuum dryer had better rehydration, lower shrinkage and higher total phenolic content. Also, Bozkir (2020) studied the effects of hot air drying, vacuum infrared and vacuum microwave dryers on the drying kinetics and quality characteristics of orange slices. The study's findings revealed that vacuum microwave dryers and vacuum infrared dryers are superior to hot air dryers for drying orange slices because they preserve the quality characteristics of the dried orange slices. Additionally, Hussein *et al*. (2018) investigated the effects of drying methods such as open sun, solar and hot air on the chemical properties of okra slices. Their results provided evidence that the solar drying produced better nutritional and sensory qualities.

2.17 Effect of Okara inclusion on Nutritional and Sensory Properties

Sensory properties of food products are generally evaluated using the human senses of sight, smell, touch, taste and hearing (Watts *et al*., 1989). Some of the sensory attributes include appearance (colour), taste, flavour (aroma), texture (mouthfeel) and overall acceptability. Typically, the sensory performance of any food product is determined by experimentation (Junaid *et al*., 2013). Meilgaard *et al*., (2007) described colour as the first thing a consumer sees before accepting a food product and flavour as the overall perception of the product's taste and aroma.

Atlaw *et al*. (2020) investigated the nutritional and sensory quality of *kocho* (flat bread) mixed with whole soybean flour and okara. The sensory's outcome showed that all the formulations were in a range that was accepted by the panelists. The addition of both soybean and okara also increased the protein and fat contents of *kocho* significantly. The study concluded that it is possible to improve the nutritional quality of *kocho* by partially incorporating whole soybean flour and okara without considerable effect on consumer acceptance of the product. Additionally, Bhavya and Prakash (2018) carried out a study on the sensory and nutritional quality of okara-enriched buns. The study revealed that incorporating okara lowered the sensory scores of the buns but improved the nutritional properties.

Furthermore, the study of Waliszewski *et al*. (2002) on corn tortillas made from nixtamalized corn flour fortified with okara showed that tortillas enriched with okara at levels greater than 10 % were rejected due to the okara's flavour. However, the tortilla enriched with okara at 10 % gave a high level of protein and excellent amino acid composition of lysine, tryptophan, isoleucine and threonine. Hence, the study recommended the use of dried okara for the enrichment of tortilla. Moreover, Su *et al*. (2013) revealed that burgers formulated with okara 60 % okara had less calories than that of commercial beef burgers. The results gotten from the sensory evaluation revealed that juiciness, tenderness, appearance and overall acceptability of okara-enriched beef burgers were not statistically different from the control (without okara). In conlusion, okara was found to be a non-meat protein source in the production of reduced-fat beef burgers without affecting their sensory quality. Again, Turhan *et al*. (2009) characterized raw beef patties and cooked beef patties with four levels of okara powder (2.5. 5.0, 7.5, and 10 %). The inclusion of okara to the raw beef patties improved its protein, fat, ash and carbohydrate content but reduced the amount of cholesterol of both the raw and cooked beef patties by about 2-28% and 6-23%, respectively. The okara had a statistically significant effect on the sensory properties. Nonetheless, when the okara inclusion level exceeded 7.5 percent, the overall acceptability scores of the samples decreased. Following this, the study recommended using up to 7.5 % okara powder as an extender in beef patties production to improve upon certain quality parameters. Also, Ostermann-porcel *et al.* (2017) developed gluten-free cookies by the use of okara and commercial manioc flour. The study found that by incorporating okara increased the protein and fibre contents of the cookies and the sensory evaluation concluded that the cookies were greatly accepted. Noriham *et al.* (2016) conducted a study to determine the physicochemical and sensory properties of okara-enriched sausages. Sensory results showed that the 20 % okara-enriched sausages were accepted while above 20 % okara inclusion resulted in poor and unaccepted texture and taste.

Guimarães *et al*. (2018) investigated the use of okara in the formulation of *paté* in order to yield a product with good acceptability and nutritional quality and found that the *paté* enriched with okara gave low energy level and high protein level of 89.65cal/100g and 3.07g/100g, respectively. Also, Zinia *et al*. (2019) in processing *roti* and *paratha* substituted wheat flour with okara found that the inclusion okara at the different ratios increased the nutrient content of the *roti* and *paratha*. The study of Enez-Escrig *et al*. (2008) revealed that rats fed with 10 % okara showed lower weight gain, lower total serum and cholesterol levels but had an increased butyrogenic effect and antioxidant status in their cecum. The enhancement of apparent absorption and retention of calcium was appreciated and there were no adverse effects from ingestion of okara that were identified in the study.

In addition, okara was used as a source of antioxidants against lipid oxidation in milk enriched with omega-3 and bioavailability of bioactive compounds after *in vitro* gastrointestinal digestion (Vital *et al*. 2018). It was reported in the study that okara displayed antioxidant capacity and decreased lipid oxidation in milk enriched with omega-3 fatty acids during light exposure. It was observed that after the digestion process, the addition of okara to milk revealed the highest content of phenolic compounds with antioxidant activity and those bioactive compounds present in the milk could act as the free radicals in humans. In conclusion, the study revealed that okara could potentially be considered as an antioxidant ingredient that will offer a cheap and efficient source of antioxidants for food products.

Satheesh and Tolera (2018) found that the incorporation of okara into cookies improved (45-47 %) the nutritional content as compared to wheat (18-20 %) and red teff (33-38 %). Research conducted by Kamble *et al*. (2019) aimed at examining the impact of varying okara (10-50 %) on physicochemical attributes, *in vitro* digestibility, and structural attributes of okara-enriched functional pasta. The results of the study showed that the okara inclusion improved the nutritive value. Likewise, research performed by Kang *et al*. (2018) where okara-enriched rice noodles showed the possibility of a reduced starch digestion. Wickramarathna and Arampath (2003) also disclosed that the physico-chemical characteristics and sensory attributes of okara –substituted bread at 10 % level were not significantly different from that of wheat bread only, without okara. This confirmed that okara could be used to improve the nutritional quality of bread and its substitution in the bakery industry would be beneficial in reducing wheat flour usage.

The wide range of literature on the incorporation of okara into food products provided above indicates the very high possibility of okara being incorporated into low-protein staples like *tuo zaafi*.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study area, research materials, and design

The okara production was conducted in a local soy processing facility at Kumbunyilli, a suburb of Tamale in the Northern region of Ghana. The different pretreatments (no pressing, 12 hours pressing and 24 hours pressing) samples were prepared separately to avoid mix up of the samples. The soybean variety used was *Afayak*.

The drying of wet okara obtained was done using three different drying methods: solar drying, sun drying and hot air drying. The sun and hot air drying were carried out at the Laboratory of the Food Science and Technology Department of the University for Development Studies, Nyankpala. Solar drying was done using a solar dryer at the CSIR-Savanna Agriculture Research Institute (SARI), Nyankpala, in the Northern region of Ghana. Data logger (HOBO Pro V2 U23-002, Onset, USA) was used to record temperature and relative humidity during the drying period.

3.2 Experimental Design

The experiment was conducted using a 3×3 factorial design. Three (3) pretreatments (no pressing, 12 hours pressing and 24 hours pressing) and three different drying methods (solar drying, sun drying and hot air drying) were employed.

3.3 Preparation of Okara

Approximately 5 kg of soybean oilseeds were soaked for 5 hours in 17 litres of water. The soaked beans were then washed and rinsed thoroughly under running water. Approximately, 14 litres of water was used in milling to obtain a thick slurry, followed by additional 20 litres of water and stirred thoroughly to obtain an even mixture, that was free of lumps. The smooth slurry was later filtered with a cheesecloth. A mechanical presser was used effectively to separate the okara from the milk. The okara was later transferred into a sack, and a 34.40 kg load (an irregular shaped stone) was put on it to further press for 12 and 24 hours. The same procedure was used to obtain the control sample, but with the control, no pressing was done (Plate 3.1).

Plate 3.1: Fresh okara

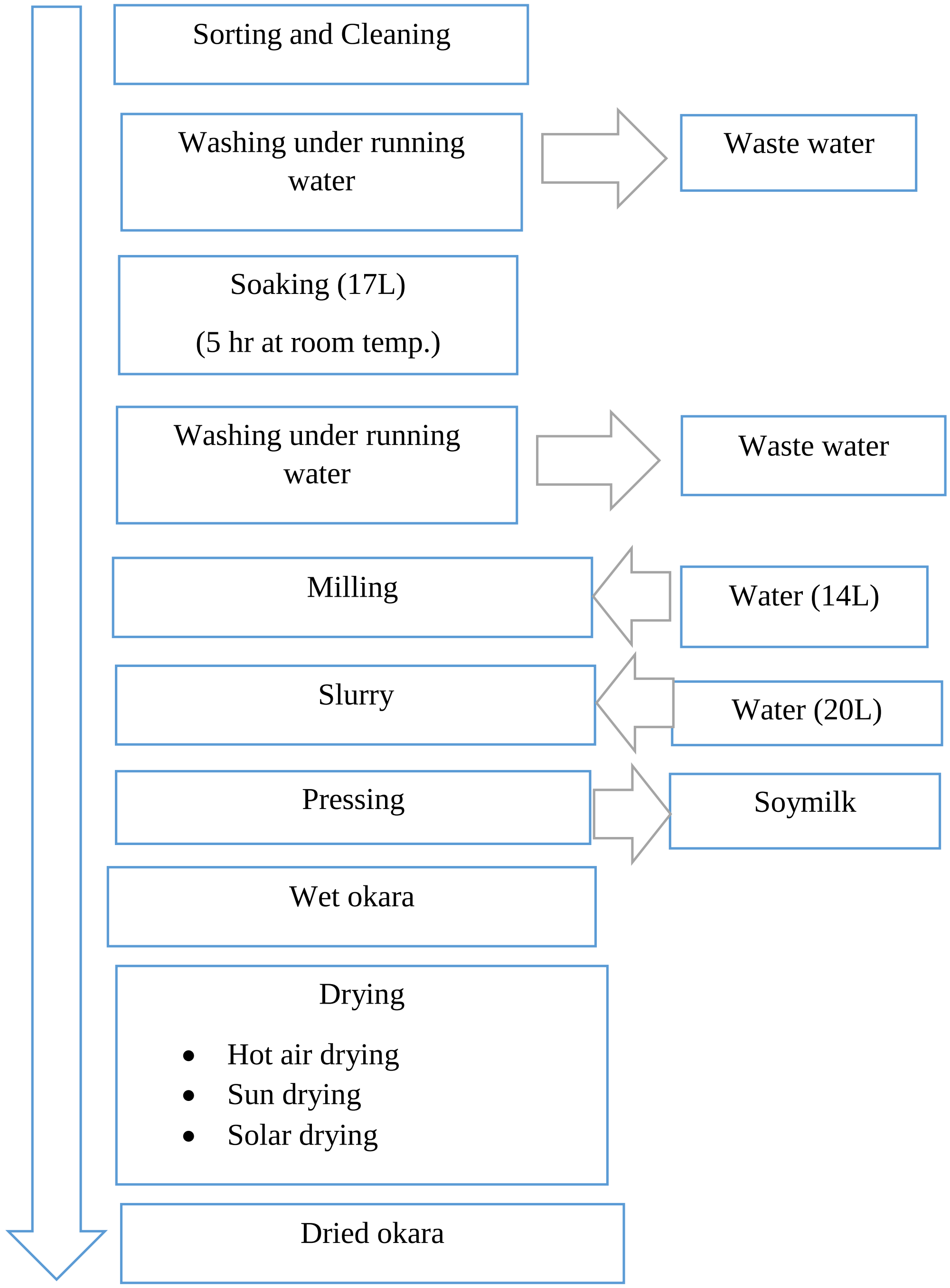

Figure 3.1: Schematic flow of okara processing

Chinese method of extraction following the process by Kamble and Rani (2020)

3.4 Drying of Okara

The okara samples of the various pretreatments (no pressing, 12 hours pressing and 24 hours pressing) were then dried using solar, open sun and hot air drying methods.

3.4.1 Solar Drying Of Okara

For solar drying of the wet okara samples, a solar house at CSIR-SARI, was used (Plate 3.2). The pretreatments of okara (3 kg each) were evenly spread on metallic trays and left in the drying chamber to dry with descriptions on the trays for easy identification. A data logger was placed in the chamber to help monitor the temperature and relative humidity during the drying process. Moisture content was monitored on hourly basis. The drying was done in triplicate.

Plate 3.2: Solar drying of samples at the solar house

3.4.2 Sun Drying

For sun drying, the pretreated wet okara samples were spread separately on metallic trays and left in the open sun for the sun's heat to dry the samples (Plate 3.3). A data logger was also placed in the sun to record the temperature and relative humidity during the drying process. Moisture loss was measured every hour. Drying was done in triplicate.

Plate 3.3: Sun drying of samples in the open sun

3.4.3 Hot air Drying

The hot air drying was done using an electric oven (SFG 3-4; China) (Plate 3.4) and was set to a temperature of 60 ºC. The three (3) treatments were spread on different trays and put in the oven. The oven had an outlet on top to allow excess heat out of the chamber. Moisture loss was also monitored hourly and drying was also done in triplicate.

Plate 3.4: Electric drying of samples

3.5 Physicochemical Analysis

Parameters such as moisture, crude protein, crude fat, ash, and total carbohydrate were determined using the standard methods of AOAC.

3.5.1 Determination of Moisture

The moisture content was estimated following the Air-Oven method as outlined by AOAC 925.10 (1990). About 5g of okara sample was oven-dried at 105 °C for 12 hours. The moisture content (%) was calculated as shown in Equation 3.1.

$$MC = \frac{W_1 - W_2}{W_1} * 100 \qquad 3.1$$

Where:

MC = Moisture content

W_1 = initial weight

W_2 = final weight

3.5.2 Determination of Crude Protein

Crude protein content was determined using the Kjeldhal method as described by AOAC 984.13 (1990). The procedure involved sample preparation, direct digestion, distillation and titration. Crude protein was estimated using the formula below (Equation 3. 2):

$$\text{Crude Protein } (\%) = \%N * 5.78 \qquad 3.2$$

Where:

N = Nitrogen

3.6.3 Determination of Crude Fat

Crude fat was determined using the Soxtec Extraction apparatus (FOSS ST 225 Soxtec (Ether Extractor) with CU 2055 Control Unit) following the methodology described by AOAC 920.39c (2000). Approximately 2 g of sample was weighed into a clean thimble. The thimble was then placed into an aluminium fat can containing 85 ml of ether. The experiment lasted for 65 mins. Crude fat content was estimated by the relation in Equation 3. 3.

$$Crude\ fat\ content = \frac{fat\ weight}{Sample\ weight} \times 100 \qquad 3.3$$

3.6.4 Determination of Ash Content

The ash content was determined following the procedures of AOAC 923.03 (2000). The sample (2 g) was weighed into a crucible. The crucible with the sample was then placed in a furnace and incinerated at 650 °C for 7 h. The ash content was calculated as shown in Equation 3. 4.

$$\%\ \text{Ash Content} = \frac{W_1}{W_2} * 100\% \qquad 3.4$$

Where;

W_1 = Weight of ash; and W_2 = Weight of sample

3.6.5 Determination of Total Carbohydrate

The standard method for determining carbohydrates in food is by deducting from the total weight the sum of the measured moisture, ash, protein, and fat respectively (Equation 3. 5).

$$\%Total\ Carb = 100 - (Moisture + Ash\ Content + Crude\ Protein + Crude\ Fat) \quad 3.5$$

3.7 Preparation of Okara-enriched *Tuo zaafi*

The ingredients used for the preparation were white maize flour and okara flour. The proportion of the flours used for the formulated product has been tabulated (Table 3.1). About 4 kg of coded okara-fortified *tuo zaafi* flour was presented to groups of women to prepare the *tuo zaafi* as it is done at home, based on local recipe (Figure.3.2) . To maintain a uniform temperature of the prepared *tuo zaafi* samples, they were stored in an ice-chest before the sensory evaluation.

Table 3.2: Different proportions of okara flour and maize flour used for okara-enriched *Tuo zaafi*

Sample ID	Proportions of flours used (%)	
	Okara flour	Maize flour
845	0.00	100.00
609	10.00	90.00
917	20.00	80.00
369	30.00	70.00
174	40.00	60.00

845 was the control (0% okara flour, 100% maize flour), 609 (10% okara flour, 90% maize flour), 917 (20% okara flour, 80% maize flour), 369 (30% okara flour, 70% maize flour) and 174 (40% okara flour, 60% maize flour).

Figure 3.2: Preparation of Okara-enriched *Tuo zaafi*

3.8 Sensory Evaluation of Okara-enriched *Tuo zaafi*

The *tuo zaafi* samples prepared were subjected to acceptance test using 75 untrained panelists. About 30 g each of the five (5) randomised okara-enriched *tuo zaafi* were coded and given randomly to each person on plates for evaluation. The panelists were chosen from the Nyankpala community based on their experiences in *tuo zaafi* consumption. Before tasting each sample, the panelists were made to rinse their mouths with water to avoid carry-over effect. The sensory attributes under evaluation, and the hedonic scale, as well as the acceptability scoring system, were explained to the panelists. Before the assessment, few minutes were allocated to enable participants seek clarification. The formulated *tuo zaafi* were scored for colour, taste, stickiness, texture, mouthfeel, and overall acceptability on a 5-point hedonic scale ranging from 1= dislike extremely, 2= dislike, 3= neither like nor dislike, 4= like, and 5= like extremely. Maize flour-only *tuo zaafi* was included as a control.

3.9 Data Analysis

Proximate compositional data (in triplicate) was analysed using two-way ANOVA in GenStat (Version 12) at 95% confidence level with means separation done using Tukey post-hoc option. The sensory data was also analysed using the Kruskal Wallis test for one-way nonparametric data in XLSTAT statistical software (Version 2016) at a 95% confidence level.

The results were presented in tables and graphs.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Temperature and Relative Humidity

It was observed that as temperature increased, relative humidity decreased and vice versa (Figures 4.1 and 4.2). The temperature ranged from 33 ℃ to 46 ℃ for the open sun drying, while that for solar drying ranged from 32 ℃ to 46 ℃. Relative humidity was also varied from 35 % to 69 % for open sun drying and from 35 % to 68 % for solar drying. This shows that the temperature and humidity values during drying for both open sun and solar drying methods were similar irrespective of the day the drying took place. This is quite understandable since both methods depend on sun radiation to cause drying to occur.

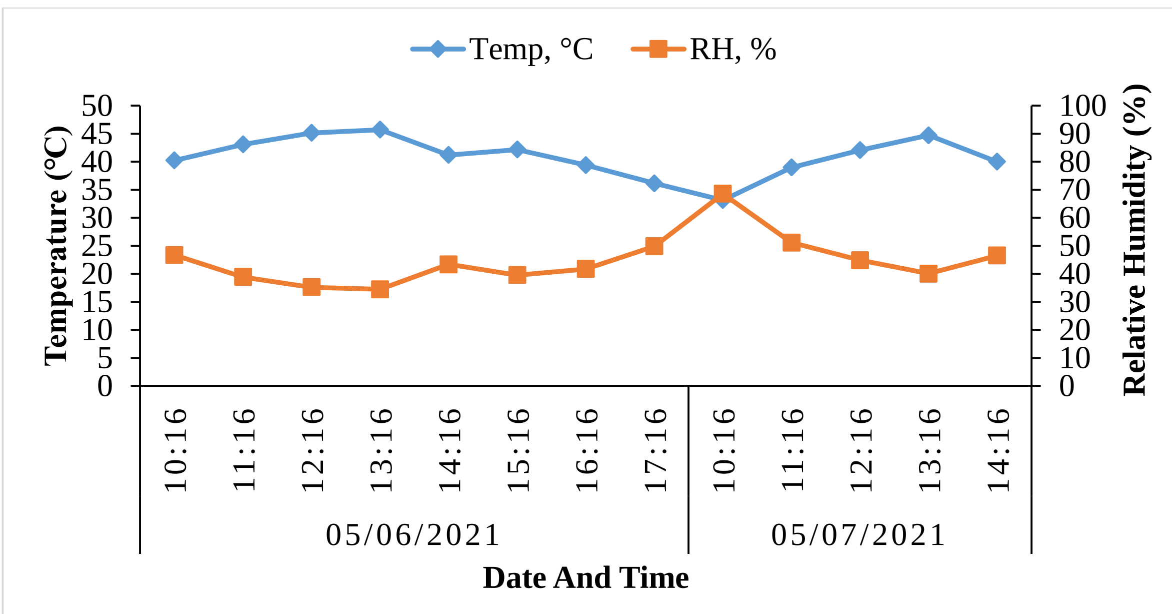

Figure 4.1: Temperature and relative humidity plot for sun drying of okara samples

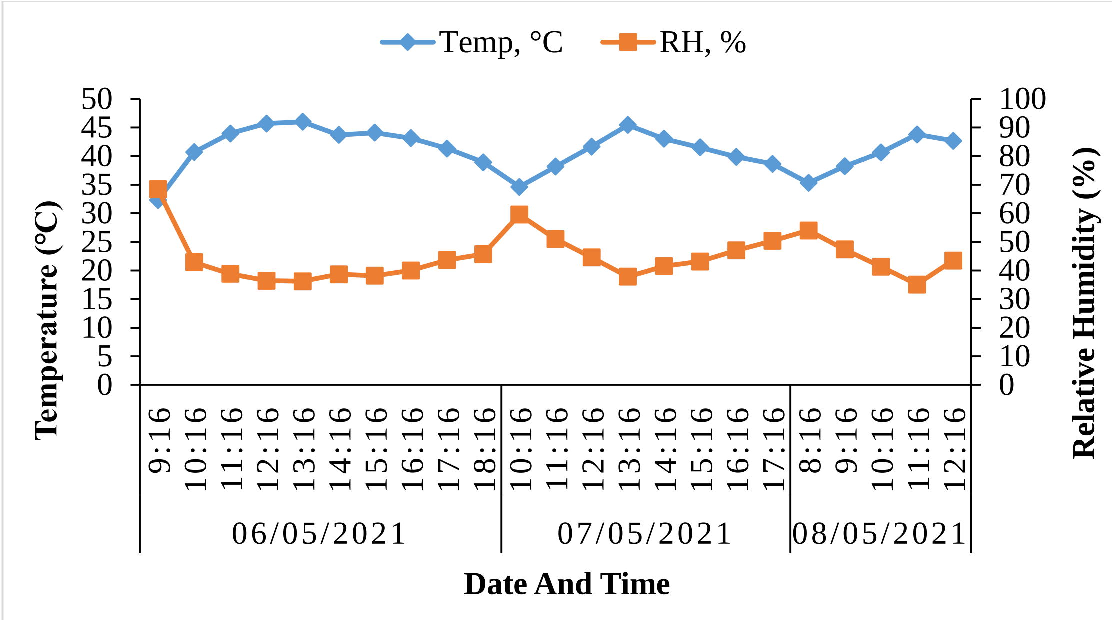

Figure 4.2: Temperature and relative humidity plot for solar drying of okara samples

4.2 Drying of Okara

Figures 4.3 – 4.8 show the drying curves for the different pretreatments of okara (no pressing, 12 hours pressing, and 24 hours pressing) under each drying method (hot air, solar, and sun). The initial moisture contents (p=0.326) of the fresh okara were 82.81 %, 81.27 %, and 79.64 % for no pressing, 12 hours pressing, and 24 hours pressing, respectively. It was observed that as drying time increased, the moisture content in the samples generally decreased irrespective of the pretreatment and drying method. This can be attributed to moisture loss as drying progressed. This finding agrees with that of Abraha *et al*. (2017) whose study was on the quality of dried anchovy (*Stelophorus hetrolobus*) using open sun rack and solar tent drying methods. Their results revealed a reduction in moisture content with an increase in drying time.

It was found out that the hot air drying (8.67±0.52 h) resulted in the fastest drying of the okara samples irrespective of whether they were pressed or not, compared to the solar (14.33±1.51 h) and open sun (9.33±0.52 h) drying methods ($p < 0.001$). This observation was primarily expected due to the constant temperature and heat intensity involved, unlike the solar and open sun drying methods, which depend exclusively on sunshine hours. Similar findings were reported by Hussein *et al*. (2018) who conducted a study on the effects of drying methods on the chemical properties of okra slices. They found out that, hot air oven drying used a shorter drying time as compared to solar and sun drying methods. However, the open sun drying resulted in a considerably shorter drying time than the solar drying, regardless of whether or not the okara was pressed before drying. The variation in drying time between the open sun and solar drying methods could best be explained by the ease of escape of the moist air from the okara samples during the drying process since the drying conditions (temperature and humidity) were similar as reported above. The samples dried under the open sun had limitless escape routes for the moist air from the samples as compared to the solar drying where the samples were dried under an enclosed environment with few exit points (Sodha *et al*., 1985). Also, moving wind (air) played a role in the drying process under open sun drying by helping moisture migrate from the wet sample. For the unpressed samples, the solar drying time was increased by 78 % and 60 % compared with the hot air drying and open sun drying, respectively. For the 12 hour pressed samples, the drying time for solar drying method prolonged the drying by 78% compared to both the hot air and the open sun drying methods. Similarly, for the 24 hour pressed samples, the solar drying time was lengthened by 88% and 67% compared with the hot air and open sun drying methods. Drying time is of great importance as far as product quality is concerned. Prolonged drying implies more energy consumption and more drying cost, for that matter. Solar drying is considered less expensive due to the use of solar energy which is provided by sunshine. Prolonged drying may also lead to nutrient losses. The longer drying recorded by solar drying is an indication of a lower drying rate as reported by Belessiotis and Delyannis (2011) that presents a risk of spoilage or moulding.

In terms of pretreatment, it was found that the pressing (10.67±2.92 h) slightly ($p=0.537$) reduced the drying time as compared to the no pressing (11.00±0.52 h). This is because the drying time decreased as pressing duration increased irrespective of the drying method used. However, the variation between the pretreatments was not very wide under each drying method. The 24 hours pressing samples resulted in a drying time of 8 hours under the three drying methods while the no pressing and the 12 hours pressing both resulted in the samples taking 9 hours to dry under the hot air drying. Similarly, for solar drying, both the no pressing and the 12 hours pressing each resulted in a drying time of 16 hours while the 24 hours pressing yielded a drying time of 15 hours, about an hour less. However, in open sun drying, the unpressed samples took 10 hours to dry while both the 12 hours and 24 hours pressed samples each took 9 hours to dry. Though the 12 and 24 hours pressing samples took the same time to dry, it was seen that the 24 hours pressed samples had a lower final moisture content (5.82 %) as compared to the 12 hours pressed samples (8.92 %). Similarly, though the unpressed and the 12 hours pressed samples took the same time to dry to a moisture content of about 10 %, the final moisture content (8.58 %) of the 12 hours pressed samples was relatively lower than that (9.41 %) of the unpressed samples. This was so because after the extraction of the okara, loads of the same weight were put on the 12 hours and 24 hours pressed samples to further drain moisture frome them before drying, whereas the upressed samples were dried right after extraction. The interaction of pretreatment and drying method did not have any significant effect (p=0.996) on the total time taken to dry the samples (Figure 4.9).

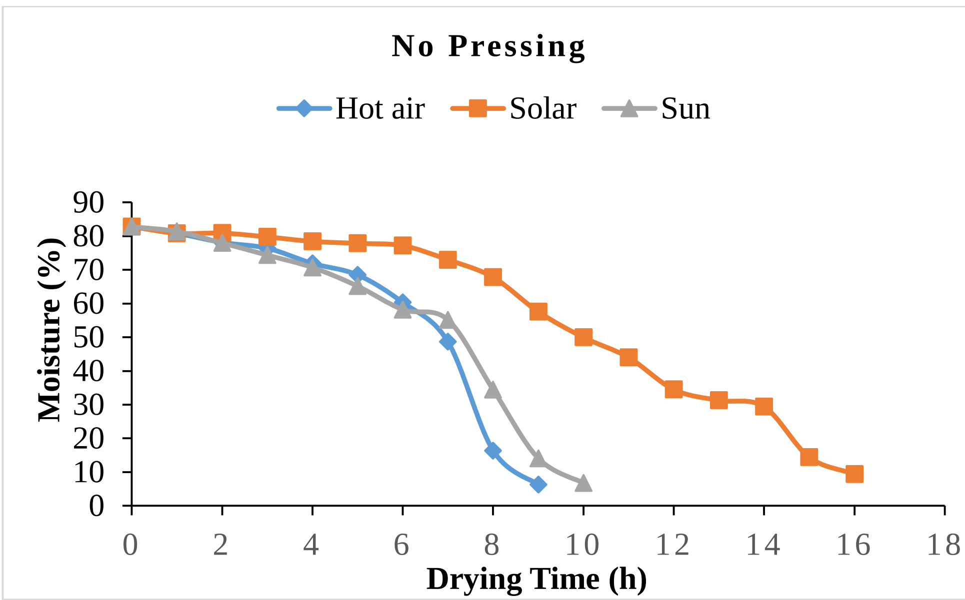

Figure 4.3: The comparison of drying curves of unpressed okara samples using sun, solar and hot air drying methods

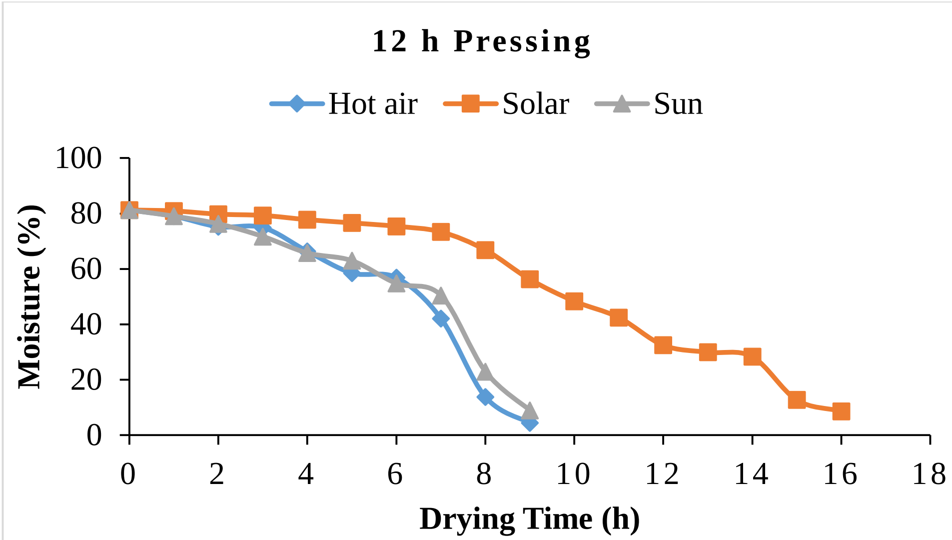

Figure 4.4: The comparison of drying curves of 12 hours pressed okara samples using sun, solar and hot air drying methods

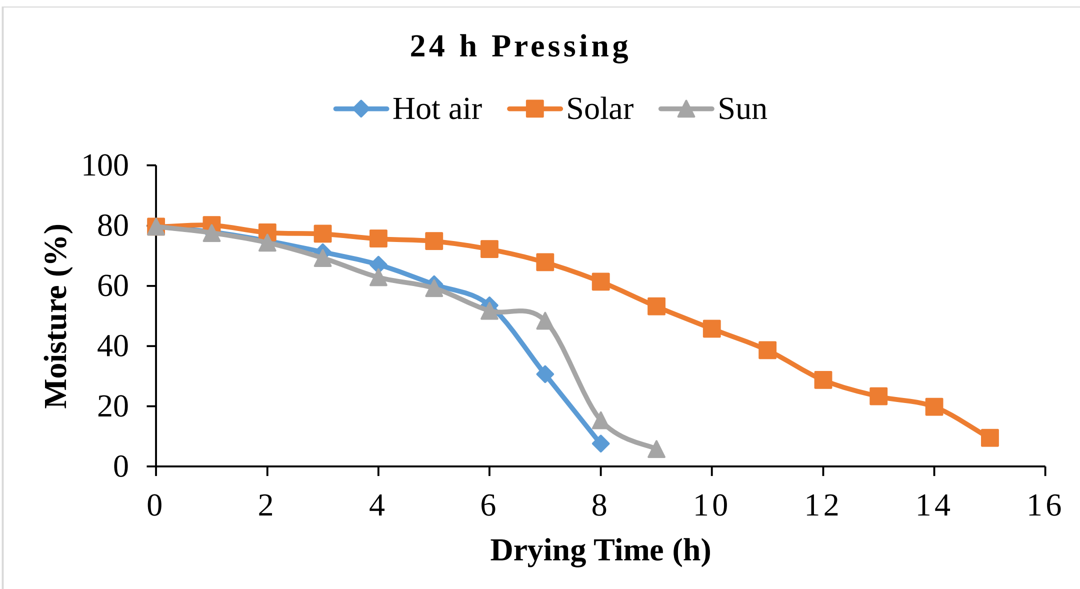

Figure 4.5: The comparison of drying curves of 24 hours pressed okara samples using sun, solar and hot air drying methods

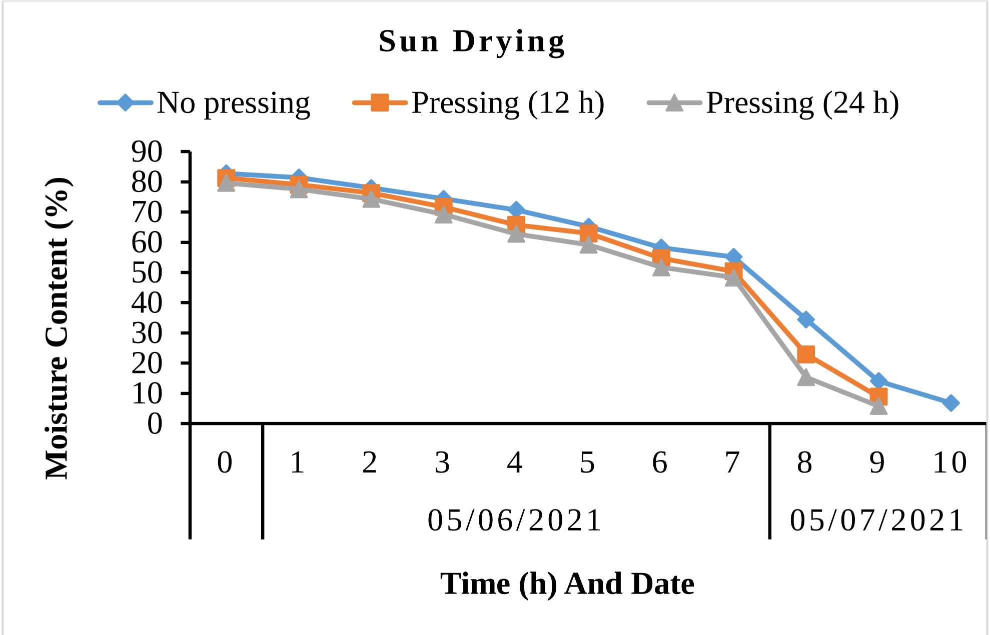

Figure 4.6: The comparison of drying curves of the three (3) pretreatments of okara using Sun drying

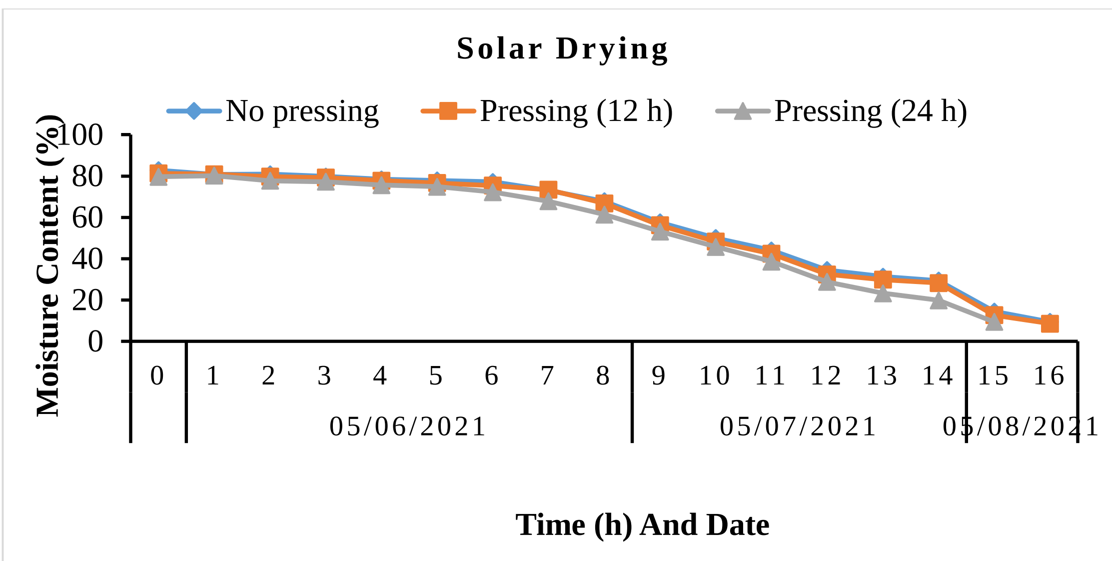

Figure 4.7: The comparison of drying curves of the three (3) pretreatments of okara using Solar drying

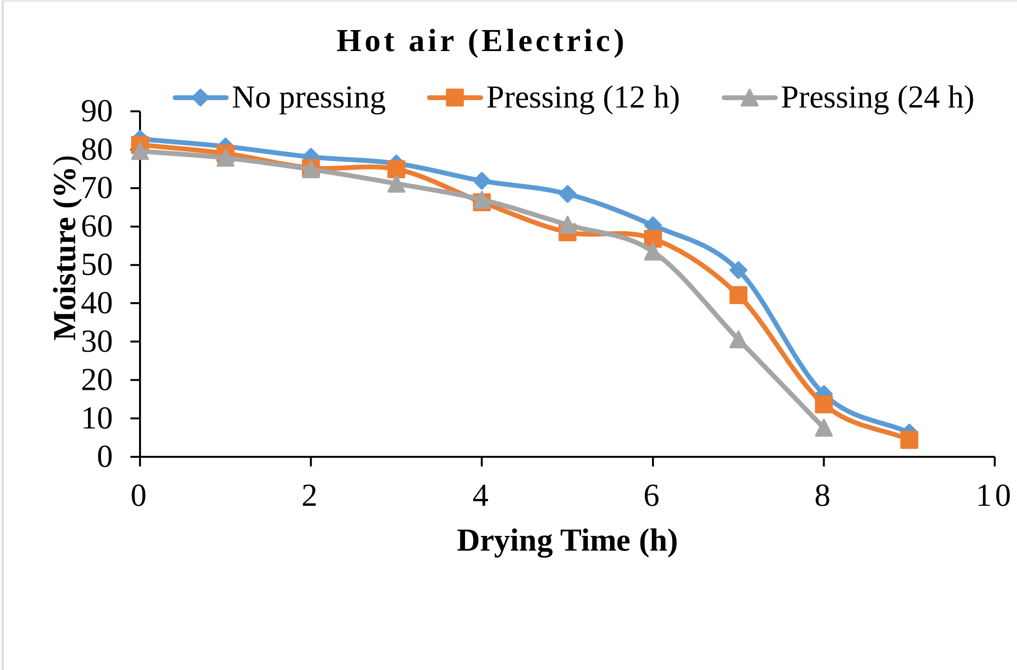

Figure 4.8: The comparison of drying curves of the three (3) pretreatments of okara using Hot air drying

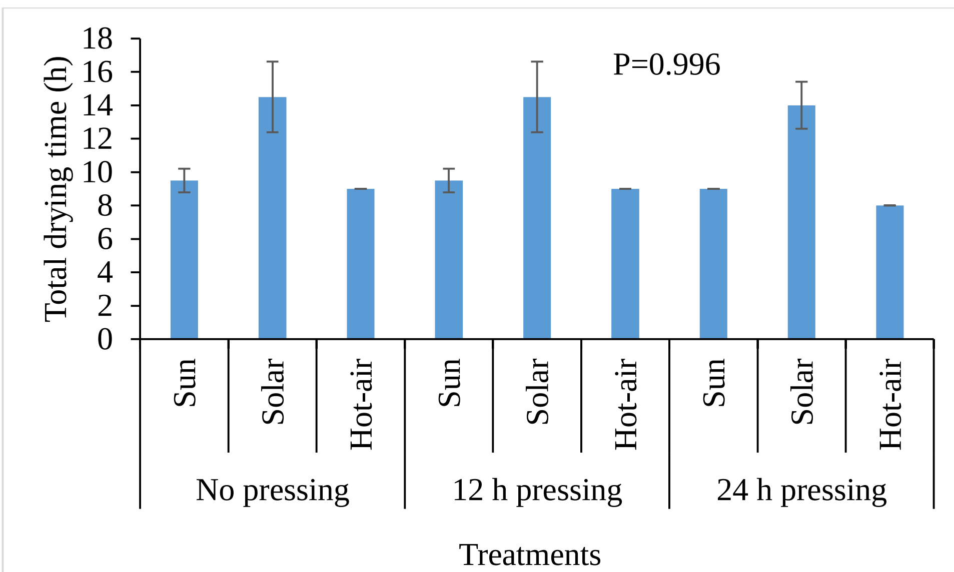

Figure 4.9: Effect of pretreatment and drying method on total drying time (h) of okara.

4.3 Pretreatment and Drying method effect on drying time and Proximate Composition of Okara

The interaction effect of pretreatment and drying methods on proximate composition of the okara samples is shown in Table 4.1. The combination of pretreatment and drying methods did not significantly affect the final moisture content ($p=0.474$) of the okara samples. Individually, drying method had a significant ($p=0.005$) effect on the final moisture content of the okara with values of 6.09±1.48 % (hot air), 6.35±1.60 % (open sun) and 9.15±0.95 % (solar) but pretreatment ($p=0.203$) did not. The low moisture content that the hot air-dried and open sun-dried okara samples had shows that they can be stored for longer periods than the solar-dried okara samples (Sengupta *et al*. 2012; Zambrano *et al*. 2019).

However, the pretreatment and drying methods produced a significant effect ($p<0.003$) on the crude protein content of the okara samples. It was found that the unpressed okara samples dried using the solar drying method recorded the highest protein value (33.14 %), which was about 1.6 times higher than the lowest value (20.72 %) recorded for the 12 hours pressed samples dried using the hot air method. The interaction effect of solar drying and 24 hours pressing samples recorded the second-highest crude protein of 31.22 %, which is statistically similar to the highest value recorded. It was seen that the okara samples whether pressed or not had the lowest protein values when hot air-dried as compared to the solar and open sun drying methods. This could partly be attributed to protein denaturation due to the relatively high drying temperature of the hot air method.

These values suggest that drying unpressed okara using a solar dryer retains more protein than any other pretreatment-drying method combination as per this study. This is because the samples were not directly exposed to the sun rays since they were dried in an enclosed structure. Protein is the main target nutrient as far as usage of okara is concerned. Protein is heat-sensitive as it undergoes denaturation and other similar reactions that are directly or indirectly dependent on drying conditions such as drying temperature and drying time (Wachiraphansakul and Devahastin, 2007). The findings of this study showed that solar-dried samples best retained the protein quality of the okara. These findings are in tandem with those of Abraha *et al*. (2017).

It was observed that the interactive effect of the drying methods and the pretreatments showed a significant difference ($p<0.036$) on the ash content. The interaction effect between hot air drying and no pressing samples gave the highest ash value (4.63 %) while the lowest (3.50 %) was recorded by the 24 hours pressed samples dried using the open sun method.

There was a significant ($p<0.001$) difference in terms of fat content that is the main effects, as well as their interaction. The interaction between hot air drying and no pressing produced the highest amount of crude fat (9.04 %), about 3.8 times higher than the least (2.39 %) amount recorded for the 12 hours pressed samples that were open sun-dried. The various interactions for crude fat were all statistically different except for the combination of solar drying and 12 hours pressing, hot air drying and 12 hours pressing, sun drying and 24 hours pressing, and hot air drying and 24 hours pressing that were statistically similar.

For total carbohydrates, no significant difference ($p=0.065$) was observed despite the values ranging from 55.26 % for the unpressed samples dried using solar to 69.62 % for the 12 hours pressed samples dried using hot air. Both pretreatment ($p<0.001$) and drying method ($p<0.001$) had significant individual effects on the carbohydrate content of the okara. The average values for no pressing (57.48±2.30), 12 hours pressing (67.00±3.33) and 24 hours pressing (62.26±3.00) all differed significantly from each other. In terms of the drying method, the values for hot air (63.47±5.53) and open sun (64.40±4.03) were significantly higher than that of solar (58.88±3.44).

Table 4.1: Effects of Pretreatments and drying method interaction on Proximate Composition of okara

Pre-treatment	Drying Method	Final moisture content (%)	Crude protein (DM %)	Ash (DM %)	Crude Fat (DM %)	CHO (DM %)
No	Sun	7.19 ± 1.95	29.00 ± 1.41^{de}	3.78 ± 0.55^{ab}	7.39 ± 0.09^{c}	59.83 ± 2.06
pressing	Solar	9.41 ± 0.97	33.14 ± 0.13^{f}	3.70 ± 0.42^{ab}	7.90 ± 0.36^{cd}	55.26 ± 0.65
	Hot air	6.30 ± 0.62	28.98 ± 0.83^{de}	4.63 ± 0.01^{b}	9.04 ± 0.10^{d}	57.35 ± 0.94
12 h	Sun	6.03 ± 0.77	25.03 ± 0.49^{b}	4.03 ± 0.29^{ab}	2.39 ± 0.25^{a}	68.55 ± 0.54
pressing	Solar	8.58 ± 0.92	27.77 ± 0.69^{cd}	3.92 ± 0.15^{ab}	5.49 ± 0.08^{b}	62.82 ± 0.92
	Hot air	4.43 ± 0.43	20.72 ± 0.52^{a}	4.12 ± 0.00^{ab}	5.54 ± 0.32^{b}	69.62 ± 0.84
24 h	Sun	5.82 ± 2.49	25.10 ± 0.27^{b}	3.50 ± 0.08^{a}	6.60 ± 0.17^{bc}	64.81 ± 0.52
pressing	Solar	9.46 ± 1.34	31.22 ± 0.31^{ef}	4.43 ± 0.09^{ab}	5.81 ± 0.53^{b}	58.54 ± 0.75
	Hot air	7.55 ± 0.73	25.76 ± 0.31^{bc}	4.20 ± 0.10^{ab}	6.61 ± 0.62^{bc}	63.43 ± 0.82
P-value		**0.474**	**0.003**	**0.036**	**< 0.001**	**0.065**

are means and standard deviations of triplicate determinations; values with different superscripts in the same column are significantly different ($p < 0.05$).

4.4 Sensory Evaluation

Table 4.2 shows the sensory properties of the okara-enriched TZ. Significant differences ($p<0.05$) were recorded for all the sensory attributes evaluated. It was found that the acceptance of the colour of the TZ decreased as the percentage inclusion of the okara increased. However, both 845 (100 % maize flour, 0 % okara flour) and 609 (90 % maize flour, 10 % okara flour) averagely fell within the hedonic scale of four (4), representing higher liking for the products. Beyond the 10 % okara inclusion level, the products were either neither liked nor disliked or disliked completely in terms of colour.

For the taste of the products, the acceptance decreased as the incorporation levels of okara increased throughout the formulations. Product 609 was comparable to 845 as there was no significant difference between them, with both approximately falling within the like category. The other products fell outside the liking range. This was mainly due to the beany taste associated with the okara flour.

For mouthfeel, acceptance also decreased significantly as the okara inclusion level increased. However, the panelists liked the 10 % okara inclusion level (product 609) and the control product (845) since both recorded values closer to the liked mark on the hedonic scale.

In terms of stickiness, the 10 % okara-enriched TZ was not significantly different from the control with both approximately falling within the category of liked (scale of 4). The other inclusion levels were within the range of 2.09 - 2.41 indicating dislikeness for the products. The acceptance of the stickiness of the products also decreased as the okara inclusion level increased.

The acceptance of the texture of the products also decreased significantly as the inclusion level of the okara flour increased. The panelists approximately liked the 10 % okara inclusion level and the control TZ as their values were about 4. The other products were again not liked by the panelists with regards to their texture.

The overall acceptability of the products showed that the acceptance decreased as the okara flour inclusion level increased. Only the 10 % inclusion level resulted in the product being liked when the values are rounded up to whole numbers. The other products were either within the neither like nor dislike category or were in the dislike category.

The acceptance level of the sensory attributes of the okara-enriched TZ shows that only the 10 % inclusion level has a greater potential to compete with the control (100 % maize TZ) on the market. Thus, inclusion levels of okara flour beyond 10 % may not produce TZ that consumers can accept based on its sensory attributes. Therefore, including the okara flour in TZ beyond the 10 % may be a waste of flour, time, and energy since the TZ's sensory attributes may not appeal to the consumer.

Table 4.2: Sensory Evaluation of *Tuo zaafi* formulations enriched with Okara flour

Sample id	Colour	Taste	Mouthfeel	Stickiness	Texture	Overall acceptability
845	4.40±0.60^{e}	4.13±0.88^{d}	4.19±0.80^{d}	3.84±0.92^{c}	4.05±0.84^{d}	4.36±0.78^{e}
609	4.00±0.74^{d}	3.79±0.87^{d}	3.56±0.93^{c}	3.52±0.92^{c}	3.76±0.71^{c}	3.87±0.76^{d}
917	3.32±0.0.87^{c}	3.07±0.91^{c}	2.89±0.85^{b}	3.01±0.97^{b}	2.97±0.85^{b}	3.12±0.75^{c}
369	2.75±1.03^{b}	2.59±1.00^{b}	2.52±0.96^{ab}	2.41±0.97^{a}	2.44±1.00^{a}	2.51±0.92^{b}
174	2.20±1.07^{a}	2.13±1.14^{a}	2.11±0.98^{a}	2.09±1.02^{a}	2.17±1.01^{a}	2.04±0.92^{a}
P-value	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**

in the same column with different superscripts were significantly different ($p<0.05$). Sensory results were reported as Mean± Standard ion. 845 was the control (0% okara flour, 100% maize flour), 609 (10% okara flour, 90% maize flour), 917 (20% okara flour, 80% maize 369 (30% okara flour, 70% maize flour) and 174 (40% okara flour, 60 % maize flour).

4.5 Proximate composition of okara-enriched *Tuo zaafi*

The proximate composition of okara-enriched *tuo zaafi* is shown in Table 4.3 below. The moisture content of the *tuo zaafi* showed significant differences between the control and the okara-enriched *tuo zaafi*. This was contrary to what Bhavya and Prakash (2018) reported in their study where the moisture content of the control and that of the okara-enriched product showed no significant difference. The protein content of the control *tuo zaafi* was significantly lower than the okara-enriched ones. The protein value for the control was 1.78, whereas the enriched TZ ranged from 2.02 % (product 609) to 2.37 % (product 174), about 1.13 to 1.33 times higher than the control. The protein level of the TZ increased as the okara inclusion level increased, similar to what was reported by Guimarães *et al*. (2018), where the enrichment of vegetable paste with okara increased its protein content as the okara concentration increased in the formulations. Likewise, the findings of Su *et al*., (2013) in beef burgers with added okara showed higher protein levels than those found in commercial beef burgers.

The fat content of the TZ increased as the amount of okara flour added increased except at 30 % where there was a marginal decline. This disagreed with the findings of Bhavya and Prakash (2018) where the fat content of the control sample of buns was higher than that of the okara-enriched buns.

The ash content of the TZ increased as more okara was added. Nonetheless, the products 845 and 609 were not significantly different from each other; likewise, products 917, 369 and 174 were not significant different $p < 0.001$)

The total carbohydrate content of the *tuo zaafi* was found to decrease as the soy residue inclusion level increased. This agreed with the findings of Bhavya and Prakash, (2018) where the enrichment of buns with okara decreased the total carbohydrate content.

Table 4.3: Proximate composition of okara-enriched *Tuo zaafi* (TZ) on wet basis (%).

Sample ID	%Moisture	%Fat	%Crude protein	%Ash	%Total carbohydrate
174	86.87 ± 0.14^{a}	0.25 ± 0.04^{a}	2.37 ± 0.12^{a}	0.27 ± 0.02^{a}	10.24 ± 0.15^{d}
369	86.16 ± 0.27^{b}	0.20 ± 0.01^{ab}	2.25 ± 0.08^{ab}	0.28 ± 0.03^{a}	11.10 ± 0.16^{c}
609	84.75 ± 0.13^{c}	0.16 ± 0.02^{bc}	2.02 ± 0.01^{bc}	0.18 ± 0.03^{b}	12.89 ± 0.11^{b}
845	84.05 ± 0.29^{d}	0.10 ± 0.04^{c}	1.78 ± 0.04^{c}	0.17 ± 0.01^{b}	13.91 ± 0.30^{a}
917	84.32 ± 0.19^{cd}	0.23 ± 0.01^{ab}	2.25 ± 0.15^{ab}	0.26 ± 0.02^{a}	12.95 ± 0.16^{b}
P-value	**< 0.001**	**< 0.001**	**< 0.001**	**< 0.001**	**< 0.001**

Values (mean ± standard deviation) with different superscripts in the same column are significantly different. 845 was the control (0% okara flour, 100% maize flour), 609 (10% okara flour, 90% maize flour), 917 (20% okara flour, 80% maize flour), 369 (30% okara flour, 70% maize flour) and 174 (40% okara flour, 60 % maize flour).

5.0 CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The primary goal of this research was to determine which drying method could best be used to dry okara while preserving its nutrient content. Also, this work set out to help incorporate dried-okara into a staple product such as *tuo zaafi* which would then contribute to improving the nutritional needs of people that are consumers of this staple, taking into account people with meagre income living in the Northern parts of Ghana.

The study revealed that hot air drying resulted in the fastest drying of the okara samples followed by the open sun drying, with the solar drying being the slowest. It was found that the method of drying had a significant effect on the proximate composition of the okara samples whereas the pretreatment only had a significant effect on all the proximate compositions except the moisture and ash contents. However, it was found that the solar drying method resulted in the samples having highest protein values compared to the open sun and the hot air drying methods. The results further showed that, the unpressed okara samples dried using the solar drying method recorded the highest protein value (33.14 %), while the 12 hour pressed samples dried using the hot air method recorded the lowest (20.72 %).

The study further showed that the acceptance of the sensory attributes of the TZ products decreased as the okara inclusion level increased. However, the TZ prepared using 10 % okara inclusion level had similar sensory attributes as the maize only TZ, while the other products were generally not liked. However, the nutritional quality of the TZ products increased as the inclusion level of the okara flour increased. This suggests that although the nutritional properties of the TZ increased with the okara inclusion level, increasing the okara level beyond 10 % did not produce consumer accepted TZ.

5. 2 Recommendation

- Okara can be incorporated up to the level of 10 % to maize flour intended TZ preparation.

5.2.1 Recommendation for further study

This research mainly focused on the proximate and sensory properties of dried okara flour and okara-enriched *tuo zaafi*. It is recommended that subsequent research focuses on the effect of short and long-term storage on okara samples to estimate the shelf-life of the products, and to determine how storage affects the nutritional and sensory attributes of the okara-enriched TZ.

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