KNOWLEDGE OF CHRONIC COMPLICATIONS AMONGST DIABETIC PATIENTS IN THE VHEMBE DISTRICT OF LIMPOPO PROVINCE, SOUTH AFRICA

by

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24 May 2018

University of Venda
I, Motsharine Selina, declare that "Knowledge of Chronic Complications Amongst Diabetic Patients in the Vhembe District of Limpopo Province, South Africa" submitted for an MCur degree at the University of Venda, has not previously been submitted for a degree at this or any other university, and that it is my own work in design and execution and that all reference material contained herein has been duly acknowledged.

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11640996

Date Signed : ..................................................................................................
DEDICATION

This research is dedicated to those who have supported me all the time, through their love, sacrifices, encouragement, and for always reassuring me that everything will be all right: my daughter, Mufunwa, and my mother, Johanna Motsharine.
Above all, I would like to thank God the Almighty, for giving me the strength and perseverance throughout the study period.

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ABSTRACT

Diabetes mellitus is a global health issue affecting people of all ages. It is defined as a non-communicable chronic disease caused by abnormal insulin production, impaired insulin utilization or both. Its prevalence and complications is increasing rapidly. The aim of this study was to assess knowledge of Diabetes mellitus chronic complications among diabetic patients in the Vhembe district of the Limpopo Province, South Africa. The study objectives were: to assess the knowledge of Diabetes mellitus chronic complications amongst diabetic patients; to determine the knowledge of diabetic patients regarding self-care practice, control and management of diabetes in the Vhembe District, and to identify challenges faced by diabetic patients regarding chronic complications of Diabetes mellitus in the Vhembe District.

A quantitative descriptive design was used. The study population was diabetic patients who were visiting the selected 4 hospitals, 2 health centers and 2 clinics were in Thulamela Municipality. Convenient sampling was used to sample 259 respondents (184(71%) females and 75(29%) males) and to select the 8 health care services. A structured, closed-ended self-administered questionnaire in Tshivenda was used to collect data on the day that diabetic patients were coming for follow-up treatment, and after they had been attended to by the health care providers. Data were analyzed using the Statistical Package for Social Science (SPSS, version 23). Ethical issues and measures to ensure reliability and validity were adhered to throughout the study.

The results show that only 112 of respondents (43%), had knowledge regarding micro-vascular complications, a smaller number (32%; n=84) of the respondents had knowledge about macro-vascular complications, whilst few (26%; n=67) had knowledge relating to nervous system complications. Recommendations to the Department of Health, health care providers, dieticians and future researchers were made in order to improve the
management of diabetes mellitus with minimal complications, and to reduce the burden of this disease.

**Keywords:** chronic complications, diabetes mellitus, knowledge, patient.
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<td>AMI</td>
<td>Acute Myocardial Infarction</td>
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<td>CHD</td>
<td>Coronary Heart Disease</td>
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<tr>
<td>CVD</td>
<td>Cardiovascular Disease</td>
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<td>DHIS</td>
<td>District Health Information System</td>
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<td>DM</td>
<td>Diabetes Mellitus</td>
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<td>FPG</td>
<td>Fasting Plasma Glucose</td>
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<td>GDM</td>
<td>Gestational Diabetes Mellitus</td>
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<td>HbA1c</td>
<td>Glycated Haemoglobin</td>
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<td>IDF</td>
<td>International Diabetic Federation</td>
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<td>KRCNSCDM</td>
<td>Knowledge Regarding Central Nervous System Complications of Diabetes Mellitus</td>
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<td>KRDMC</td>
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<td>KRMAVCDM</td>
<td>Knowledge Regarding Macro-Vascular Complications of Diabetes Mellitus</td>
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<td>KRMIVCDM</td>
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<td>OGTT</td>
<td>Oral Glucose Tolerance Test</td>
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<td>Peripheral Vascular Disease</td>
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<td>RAAS</td>
<td>Renin-Angiotensin-Aldosterone-System</td>
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<td>Acronym</td>
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<td>SA</td>
<td>South Africa</td>
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<td>SEMDSA</td>
<td>Society for Endocrinology, Metabolism and Diabetes of South Africa</td>
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<td>T1DM</td>
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EVALUATION AND ACCEPTABILITY OF BISCUITS MADE FROM WHEAT AND FERMENTED BAMBARA GROUNDNUT COMPOSITE FLOUR

By

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11626423

A mini-dissertation submitted in fulfilment of the academic requirement for Bachelor of Science degree in Food Science and Technology

Department of Food Science and Technology

University of Venda

School of Agriculture

Thohoyandou

South Africa

Supervisor: Dr. H. Silungwe

November 2017
DECLARATION

I, Mokomane Kholofelo, Student No. 11626423, declare that the dissertation herewith submitted for the Bachelor of Science in Food Science and Technology at the University of Venda, has not previously been submitted by me for a degree at any other university or institution of higher education.

...........................................  ...........................................
Student Signature                        Date
DEDICATION

I dedicate this work to my loving mother Gloria Seke Mokomane for the support and believing in my ability to achieve my dreams. When I thought of you, I would pick up my pen again and start writing this mini dissertation, you are the reason I worked harder to make sure you proud. I thank God for your life.
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Thanks to everyone whose names could not be mentioned but may have contributed in one way or another to this work. Above all, to God who made all possible.
ABSTRACT

Malnutrition is a major problem especially among children in developing countries including South Africa. This study was conducted to enhance the nutritional value of wheat flour by supplementing it with fermented Bambara groundnut flour. Biscuits were produced from wheat and fermented Bambara groundnut flour blends in the ratios of 90:10; 80:20; 70:30 (wheat flour: fermented Bambara groundnut flour) respectively. Biscuits made from 100% wheat flour were used as a control. The functional properties of the flours, proximate composition, physical properties and sensory attributes of the biscuits were evaluated. All measurements were conducted in triplicates. The results were analysed using statistical package for social sciences (SPSS version 25). There was a significant difference (P < 0.05) in the bulk density ranging from 0.76 g/ml to 0.78 g/ml among the samples. There were significant differences (P < 0.05) in moisture (4.92% - 9.84%), ash (1.32% - 2.00%), protein (9.24% - 13.82%), fat (11.23% - 15.04%) and carbohydrate (63.22% - 67.41%) contents among the samples. There were significant differences (P < 0.05) in the spread ratio (50.93 - 60.37), width (47.20 mm - 52.13 mm) and the thickness (8.63 mm - 9.27 mm) among the samples. Colour (7.60 - 8.04) and taste (7.59 - 8.14) attributes were significantly different (P < 0.05) among the samples. Consumer acceptability results showed that all biscuit samples had high rating for all evaluated attributes. Therefore, it seems that fermented Bambara groundnut flour could be used for substitution of wheat flour in the production of biscuit and its related products up to 30% substitution and still be accepted by the consumers. Consumption of the biscuits would increase the nutrient intake by the people, especially children and also increase the utilization of Bambara in developing countries, including South Africa. The nutritional composition and sensory properties of biscuits were enhanced with the addition of fermented bambara groundnut flour. The physical and functional properties of composite biscuits were improved by the supplementation of wheat flour with fermented bambara groundnut flour. Acceptable and good quality biscuits could be produced from wheat flour that is substituted with fermented Bambara groundnut flour.

Keywords: wheat, Bambara nuts, biscuit, proximate composition, sensory evaluation, physical & functional properties.
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LIST OF ABBREVIATIONS

1. PEM = protein energy malnutrition
2. FBGF = fermented Bambara groundnut flour
3. WF = wheat flour
4. BD = bulk density
5. WAC = water absorption capacity
6. OAC = oil absorption capacity
7. SP = swelling power
8. SR = spread ratio
9. CHO = carbohydrate
CHAPTER 1: INTRODUCTION

1.1 Background of the study

Protein-energy malnutrition (PEM) is a major public health problem in some parts of the world, including South Africa and the West Africa sub region (Olapade et al., 2014). This is because diets in these areas are predominantly starchy foods; the major crops are mostly roots and tubers, and cereals (Olapade & Aworh, 2012).

Biscuits belong to confectionery goods (Nwosu, 2013). Biscuits are ready-to-eat, convenient and affordable food products (Olaoye et al., 2007) and are sold in most streets in South Africa. They are produced by mixing various ingredients like flour, fat, sweeteners and water to form a dough. The dough formed unlike bread is not allowed to ferment, and then it is baked in the oven (Lake & Water-Worth, 1980). Biscuits are a rich source of fat and carbohydrate, hence are energy giving food, and they are also good sources of protein and minerals (Olaoye et al., 2007). They can be served with soft drinks or tea, and taken between meals like any other snack (Olapade et al., 2014).

Wheat (*Triticum aestum*) is one of the most important crops grown round the world and it is considered as almost first among cereal largely due to the fact that its grain contains protein with unique chemical and physical properties, and other essential nutrients (Khan & Zeb, 2007). Cereal foods are recognised as sources of caloric carbohydrates and dietary fibre. They are also sources of protein, which could be extended in the future, by compositing them with legumes (Lafiandra et al., 2014). Compositing cereals and legumes enables an affordable and feasible remedy to combat Protein-energy malnutrition, particularly among low income earners.

Bambara ground nut (*Vigna subterranean* (L). Verdc) is a legume crop of African origin used locally as a vegetable or snack. Bambara ground nut is one of the most adaptable of all plants and it tolerates harsh conditions better than most crops (Olapade et al., 2014). The seed is regarded as a balanced food because when compared to most food legumes, it is rich in iron and the protein contains high lysine and methionine (Hillocks et al., 2012). In addition, Bambara ground nut is known to contain 63% carbohydrates, 18% protein and the fatty acid content comprises predominantly linoleic, palmitic and linolenic acids (FAO, 2005).
Fermentation is an ancient process of processing cereals and legumes which not only modifies some physical characteristics of these grains but also increases the levels of nutrients, digestibility and bioavailability as well as decreases the level of anti-nutrients (Onweluzo et al., 2009). Composite flour can be described as a mixture of several flours obtained from root, tuber, cereal and legume, with or without the addition of wheat flour, which is created to satisfy specific functional characteristics and nutrient composition (Olapade et al., 2014).

Composite flours have been used extensively in the production of baked goods. In fact, several attempts have been made to produce cookies from different types of composite flours (Nwabueze et al., 2007; Okpala et al., 2011). In countries where malnutrition poses a serious problem especially among children, composite flours which have better nutritional quality would be highly desirable (Okpala et al., 2013). Therefore, biscuits can serve as a vehicle for delivery of important nutrients if made readily available to the population.

1.2. Problem statement

In Africa, most diets comprise largely cereal foods as staples (Galati et al., 2014). Nutritionally, cereals have high carbohydrate, however, they lack essential amino acids. They are rich in dietary energy, vitamins, several minerals (especially micronutrients such as iron and zinc), insoluble dietary fibre and phytochemicals with antioxidant properties (Bouis, 2000). In fact, higher daily consumption of cereals is often associated with severe protein malnutrition and may cause kwashiorkor, which manifests from chronic protein and energy imbalance, increasing susceptibility to life-threatening diseases such as tuberculosis and gastroenteritis (Rolfes et al., 2009; Rizwana et al., 2015). On the other hand, legumes are major sources of essential amino acids such as lysine and tryptophan (Temba et al., 2016). Therefore, baked products such as biscuits made from blends of cereals and legumes would be an affordable and feasible remedy to combat Protein Energy Malnutrition, particularly among low income earners due to the high cost of animal protein.
1.3. Objectives

*Main objective*

i. The aim of this study is to enhance the nutritional value of wheat flour by supplementing it with fermented Bambara groundnut flour to produce nutritive biscuits.

*Specific objectives*

i. To determine the functional properties of Wheat-Bambara composite flours.

ii. To determine the proximate composition of biscuits made from blends of wheat flour and fermented Bambara groundnut flour.

iii. To determine the physical properties of biscuits made from wheat flour and fermented Bambara groundnut composite flour.

iv. To determine consumer acceptability of biscuits made from blends of wheat flour and fermented Bambara groundnut flour.

1.4. Hypotheses

*Null hypotheses*

i. The addition of fermented Bambara groundnut flour to wheat flour will not improve the functional properties of wheat-fermented Bambara groundnut composite flour.

ii. The addition of fermented Bambara groundnut flour to wheat flour will not improve the physical properties, proximate composition and consumer acceptability of biscuits made from wheat flour and fermented Bambara groundnut composite flour.

*Alternative hypotheses*

i. The addition of fermented Bambara groundnut flour to wheat flour will improve the functional properties of wheat-fermented Bambara groundnut composite flour.

ii. The addition of fermented Bambara groundnut flour to wheat flour will improve the physical properties, proximate composition and consumer acceptability of biscuits made from wheat flour and fermented Bambara groundnut composite flour.
1.5. Significance of the study

To encourage the utilization of locally available legumes such as bambara groundnut which would serve as a good source of protein, with a great potential to address the protein-energy malnutrition problem in developing African countries.
CHAPTER 2: LITERATURE REVIEW

2.1. Composite flours and their purpose

Milligan et al., (1981) defined composite flour as a mixture of flours, starches and other ingredients intended to replace wheat flour totally or partially in bakery and pastry products. Shittu et al., (2007) also agreed with that as the composite flours used were either binary or ternary mixtures of flours from some other crops with or without wheat flour. Composite flour is considered advantageous in developing countries as it reduces the importation of wheat flour, encourages the use of locally grown crops as flour and a better supply of protein for human nutrition (Hugo et al., 2000; Noorfarahzilah et al., 2014). Local raw materials substitution for wheat flour is increasing due to the growing market for confectioneries (Noor Aziah & Komathi, 2009). Thus, several developing countries have encouraged the initiation of programmes to evaluate the feasibility of alternative locally available flours as a substitute for wheat flour (Abdelghafor et al., 2011).

Moreover, the concept of composite technology initiated by the Food and Health Organization (FAO) in 1964 was targeted reducing the cost of support for temperate countries by encouraging the use of indigenous crops such as cassava, yam, maize and others in partial substitution of wheat flour (Satin, 1988). The FAO reported that the application of composite flour in various food products would be economically advantageous if the imports of wheat could be reduced or even eliminated, and that demand for bread and pastry products could be met by the use of domestically grown products instead of wheat (Jisha et al., 2008).

The bakery products produced using composite flour were of good quality, with some characteristics similar to that of wheat-flour bread, though the texture and the properties of the composite flour bakery products were different from those made from wheat flour, with an increased nutritional value and the appearance (Noorfarahzilah et al., 2014). Apart from being a good source of calories and other nutrients, wheat is considered nutritionally poor, as cereal proteins are deficient in essential amino acids such as lysine and threonine (Dhingra & Jood, 2001). Therefore, supplementation of wheat flour with inexpensive staples, such as cereals and pulses, helps improve the nutritional quality of wheat products (Sharma et al., 1999).
According to Sudha et al., (2007), bakery products are varied by the addition of value-added ingredients. Thus, the increasing number of applications of composite flour in numerous bakery and pastry products has spurred a growing number of studies on the effects of different types of materials used to produce flour on their physicochemical and functional properties. Mepba et al., (2007) reported that the experience gained in the use of composite flours has clearly demonstrated that, for reasons of both product technology and consumer acceptance, wheat is an essential component in many composite flours. They also reported that the percentage of wheat flour required to achieve a certain effect in composite flours depends heavily on the quality and quantity of wheat gluten and the nature of the product involved. Therefore, when bakery and pastry products are produced using composite flour, their quality should be as similar as possible to those of products made from wheat flour. In this review paper, the application of composite flour its impact, following some improvements made, on the sensory qualities, rheology characteristics, and nutritional values of different types of food products are reported. The review starts with bread, followed by biscuits, and pasta (Noorfarahzilah et al., 2014).

Compositing cereals and legumes enables an affordable and feasible remedy to combat protein-energy malnutrition, particularly among low income earners. In low income countries, only 3% of dietary energy is derived from animal products, 11% from roots and tubers, and 6% from pulses, while the remainder is made up mainly from cereals (FAO, 2008). This trend of food consumption pattern portrays a major challenge (Temba et al., 2016). Within the developing countries, where malnutrition remains a significant health threat, a nutrient rich foods approach (aiming at quality, not just quantity), and facilitating dietary diversity is valuable (Schonfeldt & Hall, 2012). It is therefore, required that food products are prepared from compositing cereals and legumes in order to improve the protein and energy dietary needs in developing countries.

This is very well supported by Igbabul et al., (2015) who reported that consequent products produced from a combination of cereals and legumes possess superior nutritional and calorific value in contrast with those produced either from cereal or legume. Compositing cereals with legumes increases the protein and energy content of the food. This is a vital solution to malnutrition in Africa due to the fact that
most African diets comprise mainly of cereals as staple foods. The potential of such crops in alleviating malnutrition is imperative (Temba et al., 2016).

2.2. Protein energy malnutrition

Ernest et al., (2013) defined protein energy malnutrition (PEM) as a range of pathological conditions arising from a lack of adequate protein and calories. Protein-energy malnutrition is one of the most important public health problems in many developing countries, of which Africa is mostly affected. It is a huge burden, as it is associated with poor health and physical functioning (van der Ploos-Vijlbrief et al., 2014). This type of malnutrition presents itself in the form of kwashiorkor, marasmus and marasmic-kwashiorkor (Ernest et al., 2013; Une & Gupta, 2013) and has been associated with co-morbidities such as tuberculosis, anaemia, malaria and diarrhoea (le Roux et al., 2010) and equally considered a risk factor for death (Muller & Krawinkel, 2005).

PEM is known to affect children the most. Over 850 million people worldwide were malnourished between 1999 and 2005 with children most affected (FAO, 2005). Rizwana et al., (2015) reported that due to malnutrition, about 13 million infants and children die each year in the developing countries and in Africa alone, an average 20% do not reach their 5th birthday. In the continent, the problem of child malnutrition is seen to be more prevalent than elsewhere as more than half malnutrition-related deaths occur in SSA (Neumann, 1999; Mahgoub et al., 2006). As stated by Nassar et al., (2012), protein-energy malnutrition produces notable morphological changes in the brains of children in many developing countries. These changes affect the intellectual potential of those who survive and limit their capacity to become part of the competitive world (Cornelio-Nieto, 2007). It also affects both structure and functioning of the brain with a wide range of cognitive deficits reported in malnourished children (Kar et al., 2008).

Protein as a nutrient is considered a dietary component that evokes the widest array of complex scientific, economic and environmental issues, viewed as the most expensive but essential ingredient forming part of a healthy balanced diet (Schonfeldt & Hall, 2012). It is defined by the following measurements in children that fall below 2 standard deviations of weight for age (underweight), height for age (stunting) and weight for height (wasting) (Pinstrup-Andersen et al., 1993). Under this circumstance,
the important indicators of protein-energy malnutrition therefore, are height, weight, skin fold thickness and arm circumference with reference to age (Jones, 2004). The significant effect that such nutritional deficiency and excesses have on the health status of populations has been well recognised and alleviation of these imbalances forms part of most national health policies as both adequate food and good nutrition have been declared as basic human rights (Latham, 1997).

In Africa, where most diets comprise largely of cereal foods as staples (Galati et al., 2014), there is a threat to impoverish the bodies of those who predominantly subsist on it. Cereals supply many macro- and micronutrients necessary for human metabolic needs, however, they lack B vitamins and the essential amino acids, i.e., lysine and tryptophan. In fact, higher daily consumption of cereals is often associated with severe protein malnutrition and may cause kwashiorkor, which manifests from chronic protein and energy imbalance, increasing susceptibility to life-threatening diseases such as tuberculosis and gastroenteritis (Rolfes et al., 2009; Rizwana et al., 2015).

2.3. Wheat grain

Wheat (Triticum aestivum L.) ranks second among major cereals next to rice and plays a vital role in food security in developing countries (Braun et al., 2010). In the coming period leading up to 2020, demand of wheat for human consumption in developing countries is expected to grow at 1.6% per annum (Ortiz et al., 2008). Thus, yield increase is very much essential to maintain global food security. In the developing and under developed world, about 2.5 billion people survive on wheat as an element source of energy (FAO, 2010).

Wheat grains are generally oval shaped, although different wheats have grains that range from almost spherical to long, narrow and flattened shapes. The grain is usually between 5 and 9mm in length, weighs between 35 and 50mg and has a crease down one side where it was originally connected to the wheat flower. The wheat grain contains 2-3% germ, 13-17% bran and 80-85% mealy endosperm (all constituents converted to a dry matter basis) (Belderok et al., 2000).
2.4. Nutritional Content of Wheat Grain

Globally, there is no doubt that the number of people who rely on wheat for a substantial part of their diet amounts to several billions. Therefore, the nutritional importance of wheat should not be underestimated, particularly in less developed countries where bread, noodles and other products (e.g. bulgar, couscous) may provide a substantial proportion of the diet. Wheat provides nearly 55% of carbohydrate and 20% of the food calories. It contains carbohydrate 78.10%, protein 14.70%, fat 2.10%, minerals 2.10% and considerable proportions of vitamins (thiamine and Vitamin-B) and minerals (zinc, iron). Wheat is also a good source of traces minerals like selenium and magnesium, nutrients essential to good health (Adams et al., 2002; Fraley, 2003; Shewry et al., 2006; Tropping, 2007).

Wheat grain precisely known as caryopsis consists of the pericarp or fruit and the true seed. In the endosperm of the seed, about 72% of the protein is stored, which forms 8-15% of total protein per grain weight. Wheat grains are also rich in pantothenic acid, riboflavin and some minerals, sugars etc. The barn, which consists of pericarp testa and aleurone, is also a dietary source for fibre, potassium, phosphorus, magnesium, calcium, and niacin in small quantities. The kernel of wheat is a storehouse of nutrients essential to the human diet. Endosperm is about 83% of the kernel weight; it is the source of white flour. The endosperm contains the greatest share of the protein in the whole kernel, carbohydrates, iron as well as many B-complex vitamins, such as riboflavin, niacin, and thiamine. Bran is about 14.5% of the kernel weight (Blechl et al., 2007; Drankham et al., 2003; Shewry & Jones, 2005; Uauy et al., 2006).

Bran is included in whole-wheat flour and is available separately. Of the nutrients in whole wheat, the bran contains a small amount of protein, larger quantities of the B-complex vitamins listed above, trace minerals, and indigestible cell wall material called dietary fibre. Wheat germ is the embryo of the wheat kernel. The germ or embryo of the wheat is relatively rich in protein, fat and several of the B-vitamins (Adams et al., 2002). The outer layers of the endosperm and the aleurone contain a higher concentration of protein, vitamins and phytic acid than the inner endosperm. The inner endosperm contains most of the starch and protein in the grain. It is separated from wheat being milled for flour (Adams et al., 2002).
2.5. Background on Bambara groundnut

Bambara groundnut (*Vigna subterranea*) Figure 1. is a legume specie of African origin and belongs to the family of fabaceae and sub family of faboidea (Mazahib *et al*., 2013). It is an intermediate, herbaceous annual legume that self-pollinates with well-developed tap-root and with many profuse geotropic short lateral roots which are about 20 cm long (Arise, 2016). Bambara has lateral stems which develops from the root and on which leaves are borne. The leaves are trifoliate while petiole is long, stiff and grooved with green or purple colour base. The leaves and flower buds arise alternately at each node (Arise, 2016).

The podding of bambara groundnut of habit is similar to that of groundnut in that the pale-yellow flower stalk bends downwards after fertilization, pushing the young developing pod into the soil where it will develop and mature (Hillocks *et al*., 2012; Yao *et al*., 2015). Bambara grows well in an average temperature of 20°C - 28°C and has a growth period of at least 3 to 5 months. The plant is highly adaptable and tolerates harsh conditions better than most crops. It grows well on well-drained soil and can also grow on soil that is low in nutrients and requires pH of about 5.0-6.5. It is not prone to risk of total crop failure especially in low and uncertain rainfall (Brough *et al*., 1993; Adegbola and Bamishaiye 2011; Hillocks *et al*., 2012).

In this era of global warming and food security threat in Africa, Bambara groundnut will be a crop of hope to alleviate malnutrition and poverty as a result of its drought tolerant characteristics especially in regions of the world where water availability is a serious issue (Basu *et al*., 2007). The main producing areas of Bambara groundnut in South Africa are Limpopo, Mpumalanga and Kwazulu-Natal provinces (Hillocks *et al*., 2012). Figure 1 shows varieties of bambara groundnut (*Vigna subterranea*) differentiated based on the colour of the seed coat as red, maroon and cream.

![Figure 1: Bambara ground nut Landraces (A= Red, B= Maroon and C= Cream) (Arise, 2016).](image)
2.6. History and origin of Bambara groundnuts

Bambara groundnut (Vigna subterranea) is an indigenous African legume. Its centre of origin is believed to be in Bambara in the Timbuctoo region of Niger (Masindeni, 2006). It is cultivated from Senegal to Kenya and from the Sahara to South Africa and Madagascar. The name Bambara was taken from the district of its origin. Bambara belongs to the fabaceae family whose members also include, but are not limited to, soybean (Glycine max), cowpea (Vigna nguiculata), dry beans (Phaseolus vulgaris) and mungbean (Vigna radiata) (Goli, 1997). Bambara groundnut is also known as ntoyo (Cibemba, Republic of Zambia), jugo beans (South Africa), izindlubu (Zulu, South Africa), indlubu (Xhosa, South Africa), Kwaruru (Hausa, Nigeria), Okpa (Ibo, Nigeria), Epa-Roro (Yoruba, Nigeria) and Nyimo (Shona, Zimbabwe) (Bamshaiye et al., 2011).

There is still a debate between the Bolesedu and Venda people about who brought bambara to South Africa (Masindeni, 2006). Vendas have a strong belief that it is them, because of the name Ndluhu-mvenda’ for bambara groundnut. Farmers in the Mpumalanga province believe that bambara groundnut was possibly first introduced during dry periods when popular crops such as maize could not produce better yields (Alshareef, 2010). In South Africa, bambara groundnut is cultivated in the Limpopo, KwaZulu-Natal, Mpumalanga, Eastern Cape and Northwest provinces by few smallholder farmers (Masindeni, 2006). Rural women mainly grow bambara groundnut in their home gardens for consumption or as a cash crop for their own economic benefit (Masindeni, 2006).

2.7. Importance and uses of Bambara groundnuts

Bambara groundnut is mainly used for human consumption (Gqaleni, 2014). The seeds are consumed at different developmental stages, either immature or fully ripe. The immature seeds can be consumed fresh, boiled, grilled, as a meal or mixed with immature groundnuts or green maize (Bamshaiye et al., 2011). In Botswana for example, they are boiled with salt and eaten as a snack. In restaurants in Angola and Mozambique, boiled salted seeds are often served as appetisers (Masindeni, 2006).
Mature bambara groundnut seeds are very hard, hence boiling becomes a prerequisite before any further preparation. Ripe seeds are milled to produce flour which can be used to make biscuits and/or otherwise mixed with cereals and boiled to make porridge (Bamshaiye et al., 2011). Ripe dry seeds are also roasted, broken into pieces, boiled, crushed and eaten as a relish. In Zimbabwe, a peanut like snack is also produced through roasting of bambara groundnut and can also be dried and stored for later use (Bamshaiye et al., 2011). Bambara groundnut can also be grown for animal consumption. Initially, Bambara groundnut was used for animal feed where seeds were fed to chicks (Masindeni, 2006). The leaves are suitable for animal feed, because they are rich in nitrogen and phosphorus (Masindeni, 2006).

Recent research has established the possibility of using bambara groundnut in various food products such as biscuit and cake production (Okafor et al., 2015), vegetable milk and yoghurt (Murevanhema & Jideani, 2014). Bambara groundnut paste is used in the preparation of steamed products such as Okpa in Nigeria. Okpa is a cooked, dough-like gel made from bambara paste. It is usually wrapped in banana leaves and boiled.

Apart from its nutritional uses, bambara medicinal uses have been reported. The Lio tribe in Kenya use water from boiled bambara seeds to cure diarrhoea (Adegbola & Bamishaiye 2011). Bambara leaves are applied to abscesses and infected wounds and sap from bambara leaves is applied to the eye to treat epilepsy. Bambara roots are sometimes taken as an aphrodisiac and pulverized bambara seeds are mixed with water and used to treat cataracts in Senegal. The Igbo in Nigeria use the plant to treat venereal diseases (Hillocks et al., 2012). The black landraces have the reputation of being used for treating impotence in Botswana (Adegbola & Bamishaiye 2011). Chewing and swallowing of raw seeds is being used to curb nausea and vomiting in South African pregnant women (Jideani & Diedericks 2014).

The study conducted by Heller & Mushonga (1997) also showed that Bambara groundnuts can be consumed as milk. A trial of bambara groundnut milk was carried out which compared its flavour and composition with those of milk prepared from cowpea, pigeon pea and soybean. Bambara groundnut was ranked first, and while all milks were found to be acceptable, the lighter colour of the bambara groundnut milk was preferred. In South Africa, Swanevelder (1998) reported that ‘Sekome’ (Sesotho),
‘tihove’ (Shangaan) or ‘tshidzimba’ (Venda) is prepared by adding ‘njugo’ beans and peanuts, or just one of the two, to maize or millet-meal and boiling the mixture until it forms stiff dough. This is salted and pounded into a ball, and will often keep fresh for several days.

Additionally, bambara groundnut can also contribute towards food security indirectly (Zondi, 2012). Bambara groundnut is a legume, which has a symbiotic relationship with bacteria (rhizobia) that form root nodules. Rhizobia can make use of free nitrogen from the air, incorporating it in the plant root tissue (Masindeni, 2006), hence increasing amount of nitrogen in the soil which in turn may be beneficial to subsequent crops. Consequently, farmers may end up applying less fertiliser thus saving on much needed and scarce resources.

2.8. Nutritional profile of Bambara groundnuts

*Animal nutrition perspective*

With the increase in feed costs in the animal industry, the use of plant protein sources has become more necessary. Legumes such as soybean meal, groundnut cake and cowpea have been well utilized as plant protein sources and therefore extensively experimented and researched on. Bambara groundnut has long been used as an animal feed (Linnemann, 1991). Its seeds have been successfully used in poultry feeding (Oluyemi *et al.*, 1976). The leaves are also suitable for animal grazing because they are rich in nitrogen and phosphorus (Rassel, 1960). In weaner pig diets, up to 10% bambara groundnut inclusion level was found economical for producing affordable and cheaper pork (Onyimonyi & Okeke, 2007).

Maize is an unbalanced ration and is normally prepared with different inclusion levels of various available legumes. Bambara groundnut has high crude protein content (17-25%) (Belewu *et al.*, 2008) and can be a good protein supplement for maize diets prepared for animal consumption. Bambara groundnut varieties provide up to 25% protein when compared to other legumes. These sought after protein levels can be valuable in improving animal feed diets with low protein contents. Bambara groundnut by-products such as bambara groundnut sievate, which is a result of processing bambara groundnut into flour for human use, has undergone adequate research and it was suggested that it can be used in poultry diets (Ekenyem & Odo, 2011; Ugwu & Onyimonyi, 2008).
A human nutrition perspective

The grains of bambara make a nutritious and complete food due to its sufficient quantities of protein (20.5-24.0%), carbohydrate content (54.5-69.3%), and fat (5.3-7.8%) with the level of essential sulphur containing amino acid higher than that found in most legumes (Brough et al., 1993; Ijarotimi & Esho 2009; Mune et al., 2011; Murevanhema & Jideani 2013). Bambara is also a good source of fibre, calcium, iron and potassium. It has the potential to provide a balanced diet in areas where animal protein is expensive and the cultivation of other legumes is economically risky due to unfavourable environmental conditions (Murevanhema & Jideani 2013; Yao et al., 2015). The composition of bambara groundnut is presented in Table 1. Despite all these attributes, bambara remains underutilised and neglected even though it has the potential to play a crucial role in food security, income generation and food culture of the rural poor (Temba et al., 2016).

Table 1: Nutritional composition of Bambara groundnut grain

<table>
<thead>
<tr>
<th>Component</th>
<th>Value (Proximate g/100g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude protein</td>
<td>17.0 – 27.0</td>
</tr>
<tr>
<td>Iron</td>
<td>5.9 – 7.1</td>
</tr>
<tr>
<td>Potassium</td>
<td>1240 – 1290</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>296 – 320</td>
</tr>
<tr>
<td>Sodium</td>
<td>3.7 – 4.8</td>
</tr>
<tr>
<td>Calcium</td>
<td>7.8 – 13.5</td>
</tr>
</tbody>
</table>

Source: Hillocks et al., 2012; Adegbola and Bamishaiye 2011; Murevanhema and Jideani 2013
Table 2: Amino acid composition of Bambara groundnut grains

<table>
<thead>
<tr>
<th>Amino acids</th>
<th>Average (% protein)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alanine</td>
<td>4.4</td>
</tr>
<tr>
<td>Arginine</td>
<td>6.8</td>
</tr>
<tr>
<td>Aspartic acid</td>
<td>11.0</td>
</tr>
<tr>
<td>Cysteine</td>
<td>1.5</td>
</tr>
<tr>
<td>Glutamic acid</td>
<td>16.9</td>
</tr>
<tr>
<td>Glycine</td>
<td>3.7</td>
</tr>
<tr>
<td>Histidine</td>
<td>3.1</td>
</tr>
<tr>
<td>Isoleucine</td>
<td>4.1</td>
</tr>
<tr>
<td>Leucine</td>
<td>7.6</td>
</tr>
<tr>
<td>Lysine</td>
<td>6.7</td>
</tr>
<tr>
<td>Methionine</td>
<td>1.3</td>
</tr>
<tr>
<td>Phenylalanine</td>
<td>5.5</td>
</tr>
<tr>
<td>Serine</td>
<td>4.7</td>
</tr>
<tr>
<td>Threonine</td>
<td>3.5</td>
</tr>
<tr>
<td>Tryptophan</td>
<td>1.2</td>
</tr>
<tr>
<td>Tyrosine</td>
<td>3.4</td>
</tr>
<tr>
<td>Valine</td>
<td>4.9</td>
</tr>
</tbody>
</table>

Source: (Belewu et al., 2008).

2.9. Anti-nutritional factors of bambara groundnuts

Like many other legumes, bambara groundnut contains anti-nutritional factors such as: tannic acid, oxalates, trypsin inhibitors and phytic acid (Katungwe, 2013). Ijarotimi & Esho (2009) noted that, bambara groundnuts utilisation is impaired by the presence of these anti-nutritional factors and the stress involved in its processing. In their study, it was further observed that bambara groundnut has 2.73 mg, 0.39 mg, 46.37 mg and 6.7 mg/100g of oxalate, tannic acid, phytic acid and trypsin inhibitor, respectively. These antinutritional factors reduce mineral and amino acid
bioavailability in the body (Latham, 1997; Mann & Truswell, 2007). Trypsin inhibitors inhibit the activity of digestive enzymes whereas phytates and oxalates bind to minerals such as iron and zinc (Tibe et al., 2007). Phytic acid inhibits mineral absorption because it contains six phosphate groups with high affinity to bind cations such as iron (Amaro López & Ca´mara Martos, 2004).

2.10. Factors that influence levels of anti-nutritional factors

Levels of antinutritional factors in bambara groundnut are influenced by factors like colour and landraces (Katungwe, 2013). As regards to tannin content, Tibe et al., (2007) found out that, seeds that had the highest content of condensed tannin were brown, tan and red in colour while those with the lowest condensed tannin content were cream coloured. Low tannin bambara groundnuts are recommended for use in weaning formulae. However, it was also noted that, the content of trypsin inhibitor varied from one country to another. For instance, most of the landraces from Namibia had the highest trypsin inhibitor activity followed by landraces from Swaziland and lastly Botswana. However, most of these anti-nutritional substances are destroyed or inactivated by normal cooking or thermo-processing (Mann & Truswell, 2007).

2.11. The effect of fermentation on anti-nutritional factors

Bambara nut (Voandzeia subterranean L.) has better nutritive values than most other legumes. However, it is being underutilized due to long cooking time, anti-nutritional constituents and de-hulling constraints (Olanipekun et al., 2015). Anti-nutrients are natural or synthetic components that interfere with the absorption of nutrients (Okafor, 2015). A lot of work has been done on the effect of fermentation on anti-nutritional factors. Igbabul et al., (2014) reported that alkaloids, phytate, oxalate, saponin and hydrocyanic acid decreased with increase in fermentation time in cocoyam flour. This finding is also consistent with the results of Fardiaz & Markakis (1981), Sutardi & Buckle (1985) who reported 96.3-54.77% reduction in phytic acid content of peanut and soyabean respectively with increase in fermentation. Reddy & Peirson (1994), Sandberg & Andlid (2002) reported that the reduction in the phytic acid content may be attributed to the activity of the endogenous phytase enzyme from the raw ingredient and inherent microorganisms which are capable of hydrolyzing the phytic acid in the fermented food preparations into inositol and orthophosphate.
According to Mohmed (2003), the results clearly showed that the contents of polyphenol decreases by 24%, 21% and 13% of the karkade leaves fermented for 3, 5 and 7 days respectively compared to unfermented karkade leaves. The author also reported greater decreases in the tannin content about 38% in the karkade leaves fermented for 7 days compared to the unfermented leaves, however, clearly observed a considerable decrease about 32% and 35% for 3 and 5 days of fermentation time when compared to the unfermented sample. The decrease in tannin may be as a result of the processing which the samples were subjected to couple with the activities of the microbial enzymes involved in the fermentation (Aletor, 1993), which in agreement with the results obtained by this study, also agrees with those reported by Ojokoh et al., (2005) and Ojokoh (2006).

Fermentation has been reported to cause a general improvement in the nutritional value of legumes (Yadav et al., 2012). Whole or ground seeds, either raw or cooked, can act as substrate for fermentation. The fermented legumes are popular due to improved sensory characteristics, protein quality and digestibility and contents of some minerals and vitamins, as well as partial or complete elimination of anti-nutritional factors (Tarar, 2009).
CHAPTER 3: MATERIALS AND METHODS

3.1. Materials
The grains of Bambara groundnut (*Vigna subterranae*) were purchased at Sibasa market, Limpopo province. Cake flour, shortening, leavening agent, salt, sugar and milk were purchased at Thohoyandou Shoprite, Limpopo province, South Africa.

*Chemicals*
Sulphuric acid, potassium sulphate, hydrochloric acid, distilled water, petroleum ether, potassium hydroxide was provided by the Department of Food Science and Technology, University of Venda.

3.2. Methods

*Experimental site and design*
The investigation was conducted in the pilot plant, chemistry and sensory laboratories in the Department of Food Science and Technology and Animal Science laboratory, School of Agriculture, University of Venda. The experiment was set up as completely randomised design. The flour used for biscuit production was from blends of fermented Bambara groundnut flour and wheat flour. The flour was obtained by blending in the ratio of 100:0; 90:10; 80:20; 70:30 (wheat flour: fermented Bambara groundnut flour). The 100% wheat flour biscuit was used as the control sample. Each experiment was conducted in triplicates.

*Sample preparation*

*Preparation of fermented Bambara groundnut flour (FBGF)*
Bambara groundnut grains were sorted to remove extraneous materials and damaged seeds. The seeds were then fermented for 96h at room temperature. It was manually de-hulled and dried in an oven dryer at 60°C for 24h. The dried seeds were finely ground using Retsch (model number ZM200, Germany) at 14000 rpm for 1 minute to obtain the flour. The flour was ground to pass 1.0 mm sieve.

Bambara groundnut grains
↓
Sorting
↓
Fermentation (96h at room temperature)
↓
De-hulling
↓
Drying at 60°C for 24 h
↓
Grinding
↓
Fermented Bambara flour

Figure 2: Process flow diagram for the preparation of fermented Bambara groundnut flour (Nwosu, 2013 & Hassan et al., 2015)

Biscuits preparation

Biscuits were prepared from the blends according to the recipe shown in Table 3. The sugar and baking fat were creamed together until light and fluffy. Flours were added to the mixture followed by salt and baking powder. The mixture was thoroughly mixed into smooth dough with milk. The dough was rolled on a flat wooden tray using a hand roller and cut into predetermined size and shape using a biscuit cutter. The dough was arranged in pre-oiled trays and kept at a normal room temperature for 15 minutes to allow proper dough leavening and baked in a preheated laboratory oven operating at 190°C for 10-15 minutes. The biscuits were allowed to cool and packed in High Density Polyethylene film and stored at room temperature for subsequent analysis.
Table 3: Recipe for preparation of biscuits

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flour (g)</td>
<td>100</td>
</tr>
<tr>
<td>Salt (g)</td>
<td>0.5</td>
</tr>
<tr>
<td>Sugar (g)</td>
<td>20</td>
</tr>
<tr>
<td>Baking powder (g)</td>
<td>1.0</td>
</tr>
<tr>
<td>Baking fat (g)</td>
<td>20</td>
</tr>
<tr>
<td>Milk (mL)</td>
<td>31.5-37.5</td>
</tr>
</tbody>
</table>

Source: (Olapande & Adeyemo, 2014)

Flour (different ratios)
  ↓
Mixing of ingredients
  ↓
kneading
  ↓
Rolling
  ↓
Cutting
  ↓
Baking (190°C for 10-15 mins)
  ↓
Cooling
  ↓
Packaging
  ↓
Biscuits

Figure 3: Process flow diagram for Biscuit production (Nwosu, 2013).
3.2.1. Functional properties of wheat-bambara composite flour

Water absorption capacity (WAC)

Water absorption capacity of the product was determined by the method described by Anderson et al., (1969). Exactly 1 g of ground sample was suspended in 10 ml of distilled water in a centrifuge tube. The contents were shaken and centrifuged at 3,000 rpm for 30 min. The supernatant liquid was discarded and the remaining gel was weighed and WAC was calculated as the grams of the gel obtained per unit gram of sample (Adebowale et al., 2005; and Anderson et al., 1969).

\[
\text{Water absorption index} = \frac{\text{grams of gel}}{\text{unit gram of sample}} \quad [1]
\]

Oil absorption capacity (OAC)

For Oil Absorption capacity, 10 ml oil was added to 1 g of the flour in a centrifuge tube. The tube was agitated on a vertex mixer for 2 minutes. It was centrifuged at 3000 rpm for 30 min. The volume of free oil was recorded and decanted. Oil absorption capacity is expressed as ml of oil bound by 1 g dried flour (Adeleke & Odedeji, 2010).

Bulk density (BD)

Bulk density was determined using the method described by Onwuka (2005). About 2.5 g of sample was filled in a 10 ml graduated cylinder and its bottom tapped on the laboratory bench until there is no decrease in volume of the sample. The bulk density was calculated as weight of flour (g) divided by volume of flour (ml).

\[
\text{Bulk density (g/ml)} = \frac{\text{weight of sample (g)}}{\text{volume of sample after tapping (ml)}} \quad [2]
\]

Swelling power (SP)

This was determined by the method described by (Ocloo et al., 2010 and Abayomi et al., 2013) with modification for small samples. Accurately, 1 g of the sample was weighed into a conical flask. It was hydrated with 10 ml distilled water and heated at 80°C for 30 minutes with constant stirring in a water bath. The content was then transferred into a clean, dried and pre-weighed centrifuge tube and centrifuged at 1000 rpm for 15 minutes. The sediment was weighed in the centrifuge and swelling power was calculated. The swelling power was calculated as follows:
Swelling power = \frac{\text{weight of the paste}}{\text{weight of dry sample}} \quad [3]

3.2.2 Proximate analysis

**Moisture content**

Moisture content was determined by using oven drying method 945.32 of AOAC (2007). Accurately 2g of the ground sample was placed in a dry pre-weighed crucible and placed in an oven dryer at 105°C for 3 hours. The crucible containing the dried sample was then cooled in a desiccator for 1 hour and weighed.

\%
MC = \frac{W_2 - W_3}{W_2 - W_1} \times 100 \quad [4]

Where \( W_1 \) = weight of empty crucible, \( W_2 \) = weight of crucible + fresh sample, \( W_3 \) = weight of crucible + dry sample

**Ash content**

Ash content was determined using muffle furnace using a method 923.03 by AOAC (2007). Accurately 2g of dry sample (in triplicates) was weighed into a crucible and placed in a muffle furnace at 550°C for 3 hours. The crucible containing the sample was then cooled in a desiccator for 1 hour and weighed to calculate the total ash. The following formula was used to calculate ash content (AC) of the samples.

\%
AC = \frac{W_3 - W_1}{W_2 - W_1} \times 100 \quad [5]

Where: \( W_1 \) = Weight of empty crucible

\( W_2 \) = Weight of crucible + samples prior drying

\( W_3 \) = Final weight of crucible + ash

**Fat content**

Fat was determined according to AOAC method 920.39. The Soxhlet beaker was washed and dried in the oven for 10 minutes at 100°C. The initial mass of the beaker was measured followed by the measurement of the mass of the sample (3 g). The sample was then placed in the cellulose thimble. 100 ml of petroleum ether was poured in the Soxhlet beakers. The cellulose thimbles were placed in the Soxhlet machine for fat extraction for 3 hours 30 minutes. The beakers containing fat were removed and the amount of fat was determined by weighing the Soxhlet beaker (AOAC, 2007).
% Fat = \frac{W1}{W2} \times 100 \quad [6]

Where \( W1 \) = weight of fat extracted and \( W2 \) = weight of original sample

**Protein content**

The protein content of the sample was determined by using the Kjeldahl method using the method 978.02 by AOAC (2007). 1g of the sample was added with concentrated sulphuric acid and added with 2 tablets of potassium sulphate catalyst. The mixture was then transferred to a digestion unit there it was digested until there was a colours change. The digested solution was distilled in a distillation unit and then titrated with 0.1 M hydrochloric acid against the blank. The titre value was recorded as nitrogen percentage and it was multiplied by the factor of 6.25 to obtain the protein percentage.

\[
\%N = \frac{(100 \times N \times 14 \times V_F)T}{100 \times V_a} \quad [7]
\]

Where \( N \) = Normality of titrate

\( V_F \) = Total value of the digest = 100ml

\( T \) = Titrate value

\( V_a \) = Aliquot volume distilled

**Crude fiber content**

The crude fiber of the biscuit samples was determined according to the AOAC (2007) method 985.33. Accurately 2g of each of the samples was boiled under reflux for thirty minutes with 200 ml of a solution containing 1.25 g of H2SO4 and potassium hydroxide per 100 ml of solution. The solution was filtered through linen on a flaunted funnel and washed with water. The residue was then transferred to a beaker and boiled for thirty minutes with 100 ml of solution. The residue was then dried in an oven drier at 105 °C for 1 hour and weighed. The residue was incinerated in a muffle furnace at 540°C for 3 hours, cooled in a desiccator, and weighed.

% CF = \frac{W1 - W2}{W0} \times 100 \quad [8]

Where \( W0 \) = weight of original sample, \( W1 \) = weight of crucible + dry sample, \( W2 \) = Weight of crucible + ash
Carbohydrate content

The caloric carbohydrate content of biscuit samples was calculated using the percentages of moisture, ash, fat, fibre and protein method 970.23 of AOAC (AOAC, 2007).

\[
\text{CHO} \% = 100 - (\text{moisture} + \text{ash} + \text{fibre} + \text{fat} + \text{protein}) \tag{9}
\]

3.2.3. Determination of physical properties

Produced biscuits were analyzed for width, thickness and spread ratio according to the procedure of AOAC (2000) as the following: a) Width (W): Six biscuit were placed horizontally (edge to edge) in a row and taken their average diameter using digital venire caliper. b) Thickness: Six biscuit were placed one another and taking their average thickness using digital venire caliper. c) Spread Ratio: The spread ratio was calculated with the following formula. Where, D is the diameter, T denoted thickness and CF is a correction factor at constant atmospheric pressure and its value is 1.

\[
\text{SR} = \frac{D}{T} \times \text{CF} \times 10 \tag{10}
\]

3.2.4. Consumer acceptability

Sensory evaluation of biscuit samples from various flour blends was conducted using 80 untrained panellists drawn from the University of Venda. The test was conducted while the samples were still fresh. The panellists were required to observe the sample, taste and score. Then rinse their mouth with water before tasting another sample/product. The products were analysed based on the following parameters of appearance, texture, crispness, flavour, taste and overall acceptability using a nine-point hedonic scale (1= dislike extremely to 9 = like extremely; (Ihekoronye & Ngoddy, 1985).

3.3. Statistical analysis

All experiment was conducted in triplicates and results were presented as mean values ± standard error. SPSS version 24.0 statistical software package was used to conduct analysis of variance (ANOVA). The means were separated by Duncan’s multiple range test (values P ≤ 0.05).
CHAPTER 4: RESULTS AND DISCUSSION

4.1 Functional properties of wheat-bambara composite flour

The results of the functional properties of wheat-fermented bambara composite biscuits are shown in table 4. The bulk density values ranged from 0.76 g/ml – 0.78 g/ml. For bulk density, sample A was significantly different from the rest of the samples (B to D). Sample B, C and D had the highest values of 0.78 g/ml each while sample A had the lowest value of 0.76 g/ml. Similarly, other research worker also reported that incorporation of African breadfruit, wheat and pigeon pea flour blends increased the bulk density (Ojinnaka et al., 2016). The increase in bulk density could be an advantage in packaging of the product as it will occupy less space and could also be an advantage in solubility as the particles have less tendency of floating during soaking in liquid prior to consumption which could also improve digestion (Ayo et al., 2014).

Table 4: Functional properties of wheat- Bambara composite flours

<table>
<thead>
<tr>
<th>Sample</th>
<th>BD (g/ml)</th>
<th>WAC (g/g)</th>
<th>OAC (g/g)</th>
<th>SP (g/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.76 ± 0.01&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.85 ± 0.03&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.15 ± 0.09&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.23 ± 0.40&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>B</td>
<td>0.78 ± 0.01&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.81 ± 0.05&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.11 ± 0.06&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.84 ± 0.54&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>C</td>
<td>0.78 ± 0.00&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.78 ± 0.02&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.09 ± 0.08&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.79 ± 0.34&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>D</td>
<td>0.78 ± 0.01&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.77 ± 0.07&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.04 ± 0.02&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.74 ± 0.25&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Values are mean ± Standard deviation of triplicate determinations. Means with the same superscripts within the same column are not significantly different (P ≥ 0.05). Sample A = 100% wheat biscuit; B = 90% wheat +10% fermented - Bambara biscuit; C = 80% wheat +20% fermented - Bambara biscuit; D = 70% wheat +30% fermented - Bambara biscuits. BD (bulk density), WAC (water absorption capacity), OAC (oil absorption capacity), SP (swelling power).

The water absorption capacities of the blends ranged insignificantly (P > 0.05) from of 1.77 g/g – 1.85 g/g. The results on water absorption capacity showed no significant difference (P > 0.05) among the samples. Sample A showed the highest WAC of 1.85 g/g while sample D showed the lowest WAC of 1.77 g/g. The results showed that the WAC was decreasing with an increase in the level of fermented Bambara groundnut flour substitution. The highest WAC of wheat flour (WF) could be attributed to the presence of higher amount of carbohydrates (starch) and fibre in this
flour, this could be because starch and fibre have a good ability to associate with water under limited water condition (high hydration properties) (Adegunwa \textit{et al.}, 2017).

Oil absorption capacity of composite flours ranged from 2.04 g/g to 2.15 g/g. There were no significant differences \((P > 0.05)\) in oil absorption capacities among all the samples. The highest oil absorption capacity for composite flour was found in sample A (100% wheat) while the lowest oil absorption capacity was found in sample D (30% FBGF). These results showed that the oil absorption capacity was decreasing with supplementation with fermented Bambara groundnut flour. These results were in agreement with the observation by Adegunwa \textit{et al.}, (2017) who reported the highest value of oil absorption capacity (OAC) for plantain flour \((129.73 \pm 0.39/100 \text{g})\) and lowest for tiger nut flour \((71.62 \pm 0.88/100 \text{g})\).

Swelling power of composite flours ranged from 4.74 g/g – 5.23 g/g. There were no significant differences \((P > 0.05)\) in swelling power among formulation treatments of composite flours as well as wheat flour. Sample A had the highest values of 5.23 g/g each while sample D had the lowest value of 4.74 g/g. Swelling power decreased as the level of fermented Bambara flour increased. Swelling power is often related to the protein and starch content (Woolfe, 1992). A higher protein content in flour may cause the starch granules to be embedded within a stiff protein matrix, which subsequently limits the access of the starch to water and restricts the swelling power (Aprianita \textit{et al.}, 2009). The amylopectin is primarily responsible for granule swelling, high amylopectin content in composite flour causes an increase in the swelling power of composite flour (Tester & Morrison, 1990).

4.2. Proximate composition of wheat-bambara composite biscuits

The results for proximate composition are shown in table 5. The moisture content of the biscuits ranged from 4.92\% to 9.84\%. Sample A showed a significant difference \((P < 0.05)\) from the rest of the samples (B-D), which showed no significant difference \((P < 0.05)\) amongst them. Biscuits produced from 100\% WF had the highest moisture content (9.84\%) while the biscuit produced from 30\% FBGF substitution had the lowest moisture content (4.92\%). The moisture content of the biscuits decreased with an increase in the percentage substitution of FBGF in the biscuit dough mixes. Low residual moisture content in confectionaries is advantageous; resulting in a reduction in microbial proliferation and prolonged storage life if stored inside
appropriate packaging materials under good environmental condition (Ahmed et al., 2016).

Table 5: Proximate composition of Wheat-Bambara biscuits

<table>
<thead>
<tr>
<th>Sample</th>
<th>Moisture (%)</th>
<th>Ash (%)</th>
<th>Protein (%)</th>
<th>Crude fibre (%)</th>
<th>Fat (%)</th>
<th>Carbohydrate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>9.84 ± 0.28b</td>
<td>1.32 ± 0.29a</td>
<td>9.24 ± 0.57a</td>
<td>0.98 ± 0.04a</td>
<td>11.23 ± 0.11a</td>
<td>67.41 ± 0.67a</td>
</tr>
<tr>
<td>B</td>
<td>5.09 ± 0.15a</td>
<td>1.65 ± 0.27ab</td>
<td>11.75 ± 0.32b</td>
<td>0.99 ± 0.00a</td>
<td>13.56 ± 0.38b</td>
<td>66.96 ± 0.06b</td>
</tr>
<tr>
<td>C</td>
<td>5.00 ± 0.00a</td>
<td>1.82 ± 0.28b</td>
<td>12.06 ± 0.49b</td>
<td>1.00 ± 0.01a</td>
<td>14.45 ± 0.12c</td>
<td>65.67 ± 0.38d</td>
</tr>
<tr>
<td>D</td>
<td>4.92 ± 0.14a</td>
<td>2.00 ± 0.01b</td>
<td>13.82 ± 0.27c</td>
<td>1.00 ± 0.01a</td>
<td>15.04 ± 0.18d</td>
<td>63.22 ± 0.09d</td>
</tr>
</tbody>
</table>

Values are mean ± Standard deviation of triplicate determinations. Means with the same superscripts within the same column are not significantly different (P ≥ 0.05). Sample A = 100% wheat biscuit; B = 90% wheat +10% fermented - Bambara biscuit; C = 80% wheat +20% fermented - Bambara biscuit; D = 70% wheat +30% fermented - Bambara biscuits.

The ash content of the biscuit samples ranged from 1.32% to 2.00%. Sample A and B were significantly different, while sample C and D showed no significant difference. Sample D had the highest (2.00%) ash content while sample A had the lowest ash content (1.32%). Increase in the ash content indicates that the samples with high percentage of ash will be good sources of minerals. The ash content increased with the increase in fermented Bambara groundnut substitution. The increase in the ash content of composite biscuits may be due to the high mineral contents such as iron, phosphorous and calcium contained in Bambara groundnuts (Nwosu, 2013).

Crude protein content of composite biscuits ranged from 9.24% to 13.82%. Sample A and D were significantly different, while sample C and D showed no significant difference. Sample D showed the highest (13.82%) protein value while sample A showed the lowest (9.24%) protein value. Alozie et al., (2009) also reported an increase in protein content when wheat was supplemented with African Yam Bean flour in cake production. The protein content increased from 9.24% to 13.82% with the addition of fermented Bambara flour from 0-30%. Bambara groundnut is high in protein that play an important role in human nutrition. A detailed study shows that it contains 20-26% crude protein and makes an excellent source of supplementing
proteins in the diet (Asselberg, 1998). The biscuit produced from a blend of wheat flour and Bambara flour is expected to be better in terms of protein quality since Bambara groundnut has adequate quantity of the two limiting amino acids in cereals that is lysine and tryptophan (Giwa & Abiodun, 2010).

The crude fibre of the biscuit samples ranged from 0.98% to 1.00%. There was no significant difference (P > 0.05) among all the biscuit samples. Sample D showed the highest (1.00%) crude fibre content while sample A showed the lowest (0.98%) crude fibre content. Crude fibre content of composite biscuits increased with an increase in the substitution with fermented Bambara groundnut flour. This is because Bambara groundnut contains high levels of crude fibre than wheat flour. This statement is supported by (Abu-Salem and Abou-Arab, 2011), who reported crude fibre of 0.86 % for wheat and 3.50% for Bambara flour.

The results for fat content ranged from 11.23% to 15.04%. All the biscuit samples were significantly different (P < 0.05) from each other. Biscuits produced from 30% FBGF substitution had the highest percentage of fat (15.04%) while biscuits produced from 100% wheat had the lowest fat content of (11.23%). The results showed an increase in fat content of biscuit samples with the substitution of fermented Bambara groundnut flour. As the level of FBGF increased, the fat content increased significantly. The increase obtained in the fat contents of the biscuit samples may be attributed to the fact that Bambara groundnut flour has been observed to contain high values of fat (Chinedu & Nwinyi, 2012).

Caloric carbohydrate content of biscuits made from composite flour ranged from 63.22% to 67.41%. Sample A and B were significantly different, while sample C and D showed no significant difference. Sample A had the highest carbohydrate content of 67.41% while sample D had the lowest carbohydrate value of 63.22%. These results showed that carbohydrate content of biscuits decreased with the decrease in wheat flour. This is expected because WF has carbohydrate as its highest constituent. Other studies have also reported decrease in carbohydrate content of baked goods when cereals were blended with legumes (Okpala & Okoli, 2011; Ayo et al., 2014; Olaoye et al., 2006).
4.3. Physical properties of wheat- Bambara composite biscuits

Results for physical properties of composite biscuits are shown in table 6. The mean values for width ranged from 47.20 mm to 52.13 mm, and the spread ratio from 50.93 to 60.37 respectively. The samples varied significantly (P < 0.05) between the treatments for both the spread ratio and the width. Sample A showed the highest (52.13 mm) while sample D had the lowest (47.20 mm) values for width and sample A the highest (60.37) while sample D had the lowest (50.93) for the spread ratio respectively. The spread ratio and the width showed a decrease with the level of fermented Bambara flour substitution. This is due to the reason that protein has water binding power which restricts the increase in spread ratio and ultimately reducing it with the increased level of fermented Bambara flour supplementation (Siddiqui et al., 2003). These results were similar to the observation of Ullah et al., (2016) on biscuits from refined wheat flour supplemented with alfalfa seed flour, also Shehzad et al., 2016 for cookies supplemented with soy flour.

Table 6: Physical properties of wheat- Bambara composite biscuits

<table>
<thead>
<tr>
<th>Sample</th>
<th>Width (mm)</th>
<th>Thickness (mm)</th>
<th>Spread ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>52.13 ± 0.83d</td>
<td>8.63 ± 0.15a</td>
<td>60.37 ± 0.96d</td>
</tr>
<tr>
<td>B</td>
<td>50.03 ± 0.25c</td>
<td>8.67 ± 0.06a</td>
<td>57.73 ± 0.21c</td>
</tr>
<tr>
<td>C</td>
<td>49.07 ± 0.21b</td>
<td>8.93 ± 0.06b</td>
<td>54.93 ± 0.57b</td>
</tr>
<tr>
<td>D</td>
<td>47.20 ± 0.46a</td>
<td>9.27 ± 0.06c</td>
<td>50.93 ± 0.35a</td>
</tr>
</tbody>
</table>

Values are mean ± Standard deviation of triplicate determinations. Means with the same superscripts within the same column are not significantly different (P ≥ 0.05). Sample A = 100% wheat biscuit; B = 90% wheat +10% fermented - Bambara biscuit; C = 80% wheat +20% fermented - Bambara biscuit; D = 70% wheat +30% fermented - Bambara biscuits.

The values for thickness of the biscuit samples ranged from 8.63 mm to 9.27 mm. Sample C and D were significantly different, while sample A and B showed no significant difference. The highest mean value (9.27 mm) was found in sample D (up to 30% FBGF) while the lowest mean value (8.63 mm) was found in sample A (100% wheat) which was the control. The thickness of the biscuits was affected positively. Thickness of the biscuits showed gradual increase with the level of fermented Bambara groundnut flour supplementation. These findings were in agreement with what was observed by Awan et al., (1995), who found that the biscuit thickness was
affected positively as there was an increase in the thickness of the biscuits by increasing levels of Bambara flour supplementation. Thickness increased with increasing amount of crude fibre and crude protein.

4.4. Consumer acceptability of biscuits

Table 7. indicates the results for consumer acceptability of biscuits made from wheat and fermented Bambara groundnut composite flour as evaluated by 80 untrained panel of judges. The mean score values for appearance ranged from 7.51 to 7.85. There was no significant difference (P ≥ 0.05) among all the biscuit samples. Sample D (30% FBGF) had the highest mean score of 7.85 while sample A had the lowest (7.51). The mean values for colour of composite biscuits ranged from 7.60 to 8.04. Sample A and B were significantly different (P < 0.05) from each other while sample C and D showed no significant difference (P > 0.05). Sample B had the highest mean value (8.04) for colour attribute while sample A had the lowest (7.60) mean value.

Table 7: Consumer acceptability of Wheat-Bambara biscuits

<table>
<thead>
<tr>
<th>Sample</th>
<th>Appearance</th>
<th>Colour</th>
<th>Texture</th>
<th>Taste</th>
<th>Overall acceptability</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>7.51 ± 1.23a</td>
<td>7.60 ± 1.15a</td>
<td>7.26 ± 1.35a</td>
<td>8.14 ± 1.20b</td>
<td>7.91 ± 1.19a</td>
</tr>
<tr>
<td>B</td>
<td>7.83 ± 1.07a</td>
<td>8.04 ± 0.93b</td>
<td>7.62 ± 0.97a</td>
<td>7.85 ± 1.14ab</td>
<td>7.74 ± 0.82a</td>
</tr>
<tr>
<td>C</td>
<td>7.80 ± 1.10a</td>
<td>7.79 ± 1.10ab</td>
<td>7.35 ± 1.25a</td>
<td>7.60 ± 1.36a</td>
<td>7.59 ± 1.13a</td>
</tr>
<tr>
<td>D</td>
<td>7.85 ± 1.22a</td>
<td>7.91 ± 1.01ab</td>
<td>7.43 ± 1.15a</td>
<td>7.59 ± 1.40a</td>
<td>7.61 ± 1.20a</td>
</tr>
</tbody>
</table>

Values are mean ± Standard deviation of triplicate determinations. Means with the same superscripts within the same column are not significantly different (P ≥ 0.05). Sample A = 100% wheat biscuit; B = 90% wheat +10% fermented - Bambara biscuit; C = 80% wheat +20% fermented - Bambara biscuit; D = 70% wheat +30% fermented - Bambara biscuits.

The mean scores for texture ranged from 7.26 – 7.62. There was no significant difference (P ≥ 0.05) among all the four samples. Sample B (up to 10% FBGF) had the highest mean value of 7.62 in texture and biscuits from 100% wheat with the lowest mean score of 7.26. The values for taste results ranged from 7.59 to 8.14. Sample A and B were significantly different while sample C and D were not significantly different. Sample A had the highest (8.14) mean value while sample D had the lowest mean value of 7.59. The results showed a decrease in taste with the increase in fermented bambara groundnut flour to the dough mixes.
The results for overall acceptability of the biscuit samples ranged from 7.59 – 7.91. There was no significant difference (P > 0.05) between samples: A, B, C and D (up to 30% substitution with fermented Bambara ground nut) with mean scores of 7.91, 7.74, 7.59 and 7.61 respectively. Sample A had the highest mean score of 7.91 while sample C had the lowest mean score of 7.59 for overall acceptability. Since all the biscuit samples were moderately liked for all sensory parameters, it could be recommended that up to 30% fermented Bambara groundnut flour could be used in the substitution of wheat flour in the production of biscuits.
CHAPTER 5: CONCLUSION AND RECOMMENDATION

5.1 Conclusions

Acceptable and good quality biscuits could be produced from wheat flour that is substituted with fermented Bambara groundnut flour. The functional properties of wheat flour can be drastically improved by supplementing the flour with FBGF. Crude protein, crude fiber, crude fat and ash contents increased whereas moisture and carbohydrate contents decreased. Thus, consumption of wheat-fermented Bambara groundnut flour biscuits would increase protein intake of children, help to prevent protein-energy malnutrition among children and increase the utilization of Bambara nuts in developing countries including South Africa. The physical characteristics of FBGF–supplemented biscuits showed variable results. The thickness of the biscuits increased while the width and spread ratio decreased. Consumer acceptability results showed that all biscuit samples had high rating in terms of appearance, colour, texture, taste and overall acceptability. From the results, the null hypotheses were accepted.

5.2 Recommendation

There is no much done on the seed coat (testa) of Bambara groundnut. The seed coat of Bambara nut contains high levels of fibre. With wheat importation being expensive, the seed coat of Bambara nut could be incorporated with wheat to produce bakery and related products.
References


APPENDICES