THE FEDERAL UNIVERSITY OF TECHNOLOGY,
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HEALTHY EATING AND HUMAN DISEASE: DIETARY SHIFT IN A SUSTAINABLE FOOD SYSTEM

Inaugural Lecture Series 132

Delivered By

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1.0 PREAMBLE

"This is the day that the Lord has made, I rejoice and I am glad in it." I am indeed grateful to the Lord Almighty, the maker of heaven and earth, my help in ages past and my hope for years to come; to Him be all the glory, forever and ever. Amen.

Today, you are here to grace a very important landmark assembly in the academic community called Inaugural Lecture. An *Inaugural Lecture* connotes an academic gathering, providing opportunity for Professors to inform and relate to colleagues, the campus community and the general public of their works to date, and future plans. It is therefore, with a heart of gratitude to God for this privilege, that I deliver the 132nd Inaugural Lecture of The Federal University of Technology, Akure. It is the 49th from the School of Agriculture and Agricultural Technology. Mine is the 5th in the Department of Food Science and Technology of this citadel of academic excellence and the 2nd to be delivered by a female professor in the Department The first Inaugural Lecture in the Department was delivered by Professor T. N. Fagbemi, titled: **Food Processing: Guaranteeing Food, Nutrition and Health Security**. The second was delivered by Professor (Mrs) O. F. Osundahunsi, titled: **Food: The Fuel and Vehicle for Life**. The third was delivered by Professor I. B. Oluwalana, titled: **Give Us This Day Our Daily Fruit: Panacea to**

Wastage, Ageing and Micronutrients Deficiency Diseases. The fourth was delivered by Professor V. N. Enujiugha, titled: ***Biotechnology for Healthy Nutrition and Productive Lifestyle***. I am privileged, by the grace of God, to deliver this fifth Inaugural Lecture from the Department of Food Science and Technology, titled: ***Healthy Eating and Human Disease: Dietary Shift in a Sustainable Food System***.

Mr. Vice - Chancellor Sir, permit me to start this lecture from an historical view of how I ventured into the field of Food Science and Technology as a life career pursuit. In 1982, at Queen's School, Ibadan, my class went on excursion to the Department of Food Technology, University of Ibadan, Ibadan, Nigeria. As a young girl, I was so captivated by all that I saw; the laboratory equipment they had and the brief lecture on techniques used in food preservation. There that day, I made up my mind to study Food Science and Technology in a University. Thanks to my parents – Major and Mrs S. A. Abayomi (both of blessed memory); they did not discourage me (even though most parents of those days wanted their wards/children to either study Medicine or Law). It was the crave to become a Food Scientist that took me to Ogun State Polytechnic, Abeokuta (now Moshood Abiola Polytechnic) in 1986 and eventually University of Lagos, Abeokuta Campus, now Federal University of Agriculture, Abeokuta (FUNAAB) in 1987. So, Food Science and Technology has always been my desired course of study. Thank God for the privilege to be what I so much desired to be.

Mr. Vice Chancellor Sir, my research work of the past two decades has been in the area of food processing, products development and analysis, relating to the promotion of health and food security. The research area was borne out of the passion to contribute my quota to reducing significantly the health and economic burdens placed on our society by diet-related non – communicable diseases which could have been averted if there was more commitment to healthy eating. In this lecture, I will discuss the research outcomes of my collaboration with fellow scientists within and outside Nigeria and the contributions made through my supervision of postgraduate students, as it relates to ***Healthy Eating and Human Diseases***.

2. Keywords in the Topic

2.1 Healthy eating

The Bible, even though is not a textbook on nutrition, contains the dietary laws God gave to the Israelites through Moses (Leviticus 11; Deuteronomy 14) and serves as proof that God is interested in the food we eat and our overall wellbeing. One of the reasons God gave those laws was to shield them from certain diseases. Healthy eating therefore, is food consumption system that helps to maintain or improve the health and the overall wellbeing of man. It is such that offers the body the essential nutrition in terms of fluid, macronutrients, micronutrients and adequate calories (Lean, 2015). The essentials of healthy eating include; timing of eating (taking the last meal latest two hours before bed), choosing whole grain foods, limiting highly processed foods, taking balanced diets, eating a range of foods and eating moderately, and drinking sufficient quantity of water. Eating natural foods, particularly of plant origin, results in the availability of vitamins and minerals, and other nutrients needed for optimal health and wellbeing.

Mr. Vice Chancellor Sir, healthy eating pyramid **(Figure 1)** explains quantity of each category of food that should be eaten daily. It provides sound eating guide with more emphasis on exercise and weight control. Unhealthy eating, on the other hand, are dietary and eating habits that are not beneficial to maintaining health and wellbeing. These may include excessive consumption of saturated fats (most especially those of animal origin), foods low in fibre and vitamins, as well as junk foods. According to Merriam-Webster Dictionary, junk foods are foods high in calories from sugar or fat, with little nutritional fibre, protein, vitamins, minerals, or other important substances of nutritional value.

Figure 1: Healthy Eating Pyramid. Source: Harvard School of Public Health

2.2 Human Disease

Human disease may be defined as an impairment of the normal state of a human being that interferes or alters its vital functions. Medieval health practitioners believed in the theory that disease was caused by demons, sin, bad smells, astrology, the stars, *etc*. Ultimately, they believed that life was controlled by God and His saints, and that a plague such as the Black Death was seen as a punishment from God. Guy de Chauliac, the Pope's Physician, even blamed the Black Death on a conjunction of Saturn, Jupiter and Mars. Hippocrates, a Greek physician of the 4th and 5th centuries BCE, is credited with being the first to adopt the concept that disease is not a visitation of the gods but rather is caused by earthly influences. Scientists have since continually searched for the causes of diseases and, indeed, have discovered the causes of many diseases.

In the development of disease (pathogenesis), more is involved than mere exposure to a causative agent. Thus, in the pathogenesis of disease, the virulence of the agent and the degree of exposure, level of immunity, age and the nutritional status of the exposed person; all play significant roles in the development of diseases. Similarly, there are evidences that most diseases have their origins in the deleterious free radical reactions that occur in the body **(Figure 2)**. Oxidative stress promotes the generation of free radicals, which have significant impact in the pathogenesis of human chronic diseases; such as cardiovascular impairment, cancer, and diabetes, among others**.**

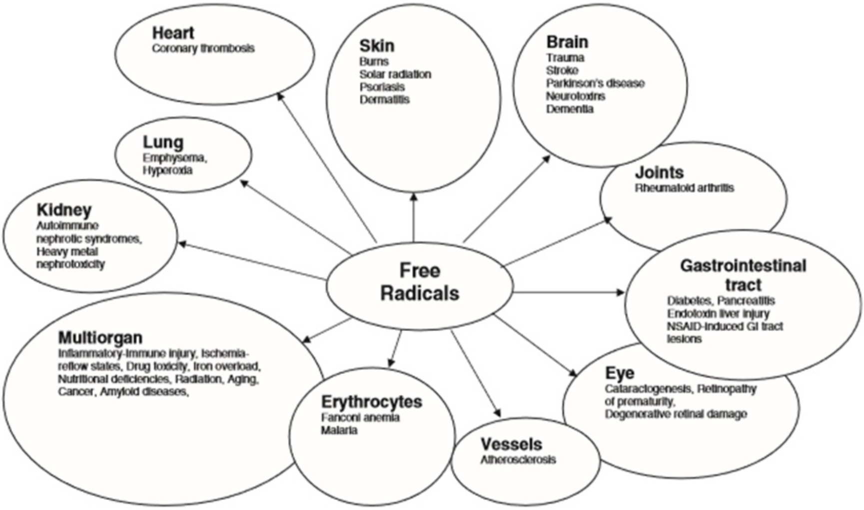


Figure 2: Overview of human diseases where excessive free radical production is thought to play a significant role. Source: Halliwell (1987).

Globally, countries of the world are confronted with the double burden of communicable diseases (CDs) and non-communicable diseases (NCDs). Developing countries are more susceptible to these diseases than developed countries due to a range of environmental and social factors, such as; poor sanitation, lack of potable water, poverty, malnutrition, unhealthy diets, harmful use of tobacco and alcohol, and physical inactivity.

NCDs which include cardiovascular diseases, diabetes, cancer, obesity, mental disorders, among others as well as the CDs such as HIV/AIDS, malaria, tuberculosis, respiratory infections and diarrhoea among others are on the increase in developing (low/middle income) countries with their consequences. Apart from the high rate of morbidity and mortality caused by both NCDs and CDs in developing countries, the global burden also consists of economic losses from declined or lack of productivity whenever the bulk of the labour force are affected. In sub-Saharan Africa (SSA), the distressful effects of these diseases are obvious with respect to life expectancy and the Human Development Index (HDI). The impact of CDs can be alleviated through the formulation and execution of evidence-informed healthcare policies and strategic planning, resulting in inexpensive consultation and management regime, introduction of new vaccines and medicaments, *etc*. However, the main burden caused by NCDs could be evaded by accepting it as part of the essential primary health care package and engaging preventive methods, such as; regular check-ups for early diagnosis and detection; and through elimination of risk factors (junk diets, risky smoking and alcohol consumption, physical sedentariness, gluttony, *etc.*) and dietary shift.

NCDs account for 80% of the global disease burden and 70% deaths in developing countries such as ours (Nigeria) are caused by NCDs, with half of the deaths occurring in people less than 70 years of age (WHO, 2013). It is the drive to contribute my own quota to the reduction of this burden and the increasing health care costs of NCDs that informed my area of research. It is worth noting that ***dietary shift*** is a major means by which NCDs can be combatted since we have a food system that is sustainable in Africa. This implies shifting from modern unhealthy diets and dietary patterns, characterized by the consumption of high calories, proteins from red meat, and animal-based fatty foods, to the traditional (old) diets; high in fibres and phytochemicals that have the potential to reduce the incidence of NCDs and enhance quality of life.

2.3. A sustainable food system

In the context of my lecture this afternoon, I wish to refer to a sustainable food system as a form of food system that offers healthy diets to the populace from underutilized legumes, cereals and other locally grown crops. These are rich in dietary fibres, bioactive compounds such as phenolic compounds (Figure 3), minerals and antioxidants. Sustainable food system begins with the development of agricultural practices that are sustainable, development of food distribution systems that is sustainable, production of diets that is sustainable, and sustainable reduction in food wastage all through the system. The aim of a sustainable food system is to attain food and nutrition security and healthy diets while controlling the negative environmental effects and improving socio-economic value.

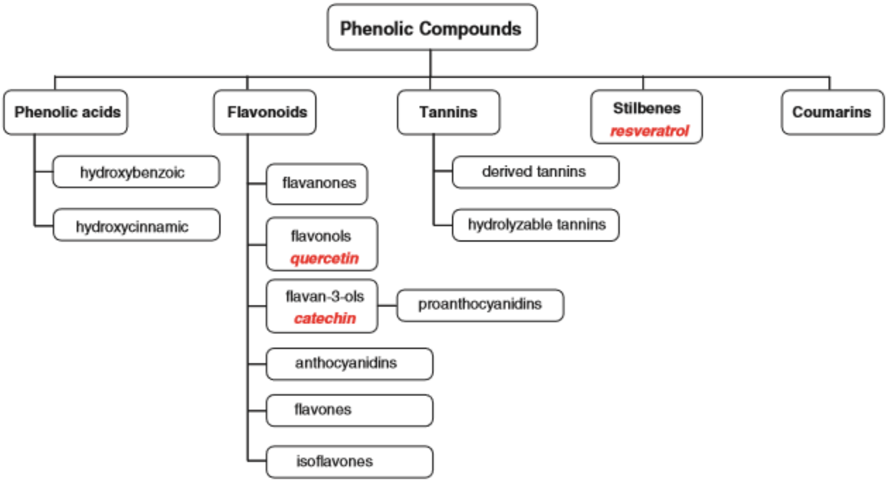


Figure 3: Classes and subclasses of phenolic compounds. Source: Erdman et al. (2007).

3.0. My Contribution to Healthy Eating for Optimal Health and Wellbeing

3.1. Exploration of cereals and pseudo-cereals in the control of NCDs

Cereals and cereal products are important staple foods in human diets especially in sub-Saharan Africa (Fasasi *et al.,*2006, 2009). They provide good percentage of world's population requirements for nutritional energy, protein as well as micronutrients. Major cereal crops are wheat, rice, maize, sorghum, millets, barley, oats, and rye. Whole cereals are low in fat, excellent sources of phytochemicals and fibres. Despite the significant contribution of cereals to human nutrition, they are not sufficient for life sustenance because they are deficient in some micronutrients like vitamins A, D and iodine, and cereal proteins are limited in lysine. However, the application of traditional and technological processes over the years have resulted in the production of various cereal – based foods with modified nutritional values.

Pseudo-cereals are non-grasses (true cereals are grasses) that are used in much the same way as cereals but they have nutritional properties (protein contents and qualities) better than cereals. Examples of pseudo-cereals are amaranth, buckwheat, and quinoa. Pseudo-cereals contain dietary fibres in high proportion, which improves lipid metabolism (Venskutonis & Kraujalis, 2013).

My research work on cereals in the past two decades has been on non-wheat cereals such as maize, sorghum, and millets; the reason for this is because wheat is not native to Africa (Nigeria in particular). This consequently will promote the consumption of our local underutilized crops and encourage peasant farming; with resultant reduction in the cost of wheat importation and thus increase our Gross Domestic Product (GDP). Considering this submission, you will agree with me on the relevance of the development of non-wheat products as ***healthy eating component that should be sustained.***

3.1.1. Maize (*Zea mays*)

Maize is a major staple crop in SSA and it is the most important cereal crop because it serves as staple food for over 1.2 billion people in SSA and Latin America. It is consumed in various forms; such as main dishes, infant foods, snacks and gruels (*ogi*). In developing countries, such as Nigeria, malnutrition persists as a principal health challenge among children below five years of age and most traditional weaning foods made from maize are of poor protein qualities. Efforts to improve the nutritional value have been based on fortification with legumes to provide the deficient amino acids. However, these efforts had resulted in products with improved nutritional quality but compromised organoleptic properties and poor digestibility attributed to the low solubility of plant proteins (Fasasi *et al*., 2009). My PhD research focused on the development of maize - tilapia gruel of high protein quality, good digestibility and improved functional and organoleptic properties. Fasasi *et al.* (2005, 2006, 2007) reported the development of high digestible proteinous maize mix, using underutilized Nile Tilapia (*Oreochromis niloticus*); aimed at solving the problem of protein malnutrition. The choice of Nile Tilapia in fortifying maize gruel was due to their (Tilapia) high fecundity (Fagbenro 2002; Fasasi *et al.,* 2005; 2006; Fagbenro *et al.,* 2011) culminating in stunted growth, bony nature and inability to command good market price. The study revealed that fortification of maize gruel with tilapia flour increased the protein content of the maize gruel (Fasasi *et al.,* 2005). The protein content of the maize – tilapia gruel favourably compared with the protein content of a commercial weaning diet and FAO/WHO pattern of 16%.

In the same study, a multi-enzyme digestion (consisting of trypsin, chymotrypsin and peptidase) carried out on the blends revealed an improved protein digestibility in maize – tilapia blends compared to maize. Apart from the improvement in the nutritional status observed as a result of tilapia flour incorporation into the maize blends, it is worth mentioning that it also improved the functional and pasting characteristics of the maize – tilapia mix (Fasasi *et al.,* 2007). The water and oil absorption capacities (WAC and OAC) increased significantly with the incorporation of tilapia flour. These increment were attributed to the observed increase in the protein contents of the flour blends resulting in high hydrogen bonding and high electrostatic repulsion, thereby facilitating binding and entrapment of water (Fasasi *et al*., 2007). This implies that the maize – tilapia mixes have abilities to absorb water and swell for improved consistency in food. These characteristics are critical in viscous foods such as soups and gravies, and baked products. Low packed bulk densities obtained for the maize – tilapia mixes favour the usefulness of maize – tilapia mixes in the formulation of high nutrient – dense weaning foods (Fasasi *et al*., 2007). Similarly, high temperature weakened the starch granules of the mix leading to improved solubility. The mixture of tilapia flour and maize flour resulted in gruel of low viscosity, which is nutritionally beneficial in infant nutrition (Adeyemi & Beckley, 1986; Fasasi *et al.,* 2007). Dietary shift to protein-enriched-maize gruel is a healthy eating adequate to prevent protein energy malnutrition (PEM).

Lysine and tryptophan deficiency in common maize brought about the development of an alternative maize known as 'Quality Protein Maize (QPM)' through breeding achievement to alleviate protein deficiency in developing countries (Vasal, 2000). Fasasi (2009a) studied the effect of processing methods (germination, fermentation and toasting) on the proximate and functional properties of Quality Protein Maize (QPM) flour. These processing methods resulted in QPM flour of improved nutritional composition and functional properties. Fermentation improved the nutritional value of weaning foods from QPM as it converts insoluble proteins to soluble components (Fasasi, 2009a). The utilizable energy due to protein (UEDP) at 60% utilization of the processed flours revealed the fermented flour (FQM) as having the highest value; thus implying that the protein content of FQM would give more utilizable energy at 60% utilization than germinated quality protein maize (GQM) or toasted quality protein maize (TQM). Similarly, the proportion of energy due to protein (PEP%) showed that PEP for GQM and FQM are comparable to the recommended safe level of 8% (Beaton and Swiss, 1974). Fermented and germinated QPM might therefore be enough to prevent malnutrition.

It becomes imperative to produce acceptable snacks with high nutritional quality that could be useful in nutritional programmes to combat malnutrition and nutrient deficiencies. Snacks are becoming increasingly popular due to increasing urbanization, which compels many people to stay longer outside their homes; thereby becoming more dependent on snacks for the supply of part of their daily nutritional requirements. Fasasi (2012) and Fasasi & Alokun (2013) developed *Kokoro* a Nigeria maize-based snack with improved nutritional and sensorial properties as a means of shifting our diets (including snacks) away from junk diets. The physicochemical properties and acceptability of *Kokoro* from blends of maize and soy flour [full – fat (FF) or defatted (DF)] was assessed. Addition of FF and DF to maize significantly *($p < 0.05$)* improved the protein contents of *Kokoro* (Fasasi, 2012).

In similar studies, Fasasi and Alokun (2013) reported an increase in the minerals, vitamins and amino acid contents as well as the antioxidant properties of ginger-spiced *Kokoro.* Addition of soy and/or ginger powder (white or yellow) resulted in significant increase in the Ca, Mg, P, Na and K contents. Na/K ratio values (<1) obtained in this study compared favourably with the recommended value of <1 (NRC, 1989). The Na/K ratio in the body is important because it helps in controlling high blood pressure. The inclusion of white ginger increased the vitamin C contents significantly ($p < 0.05$), while the inclusion of yellow ginger increased the vitamin A contents. Vitamin C provides a protective function against free radicals. Also, the extract of ginger spiced *Kokoro* significantly inhibit 2, 2-diphenyl-1-picryhydrazyl (DPPH) as seen in **Figure 4**. The addition of ginger to maize for *Kokoro* production increased the amino acid contents of ginger- spiced *Kokoro*. This makes ginger-spiced *Kokoro* an ideal healthy snack which could effectively combat PEM as well as scavenge free radicals in the body. Awolu *et al.* (2016), studied the quality of maize-based snack supplemented with soy and tigernut flour. The blend ratios were optimized using response surface methodology; biscuits obtained were of improved nutritional qualities and exhibited high antioxidant properties. Dietary shift from modern snacks to the aforementioned maize - based snacks of improved nutritional qualities and high antioxidant properties could be referred to as healthy eating in a sustainable food system.

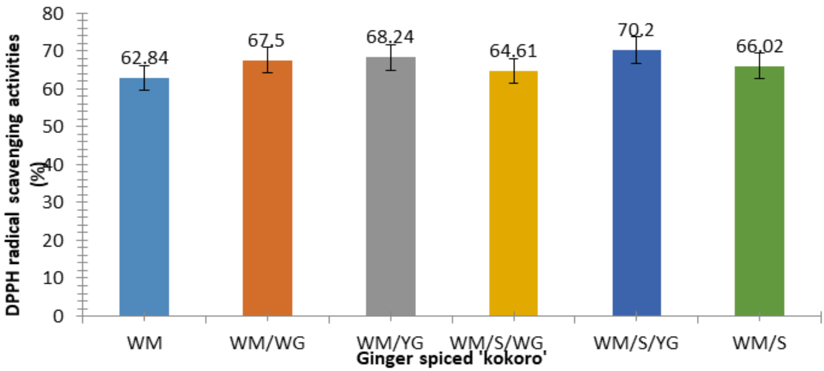


Figure 4: DPPH radical scavenging activities of ginger spiced 'Kokoro'

KEYS:

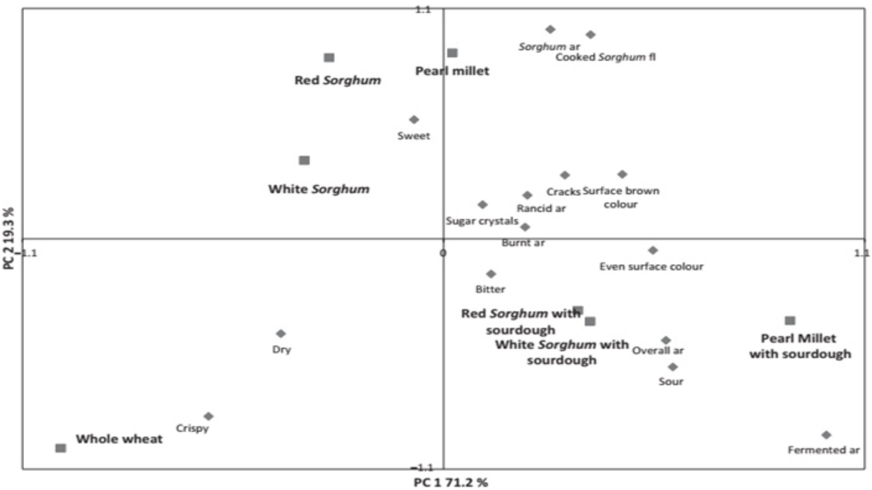
WM = White Maize; WM/WG = White Maize: White Ginger ; WM/YG = White Maize: Yellow Ginger; WM/S/WG = White Maize: Soy bean: Yellow Ginger; WM/S/YG = White Maize: Soy bean: Yellow Ginger ; WM/S = White Maize: Soy bean

3.1.2. Sorghum (*Sorghum bicolor* (L.) Moench)

Sorghum is an important staple food in Africa (Nigeria, Sudan, Ethiopia), Asia (India, China), and the drier parts of Central and South America. In Nigeria languages, it is called *oka baba* (Yoruba), *dawa* (Hausa) and *soro* (Igbo). Nigeria is the largest producer of sorghum in West Africa, accounting for about 71% of the total regional sorghum output (Ogbonna, 2011). The country is the third largest world producer after the United States and India (FAOSTAT, 2012). However, 90% of sorghum produced by United States and India is destined to animal feed, making Nigeria the world leading country for food grain sorghum production. The use of sorghum in the production of diverse healthy foods and the consumption of such foods might be a definite dietary shift from the modern diet to the traditional diet and consequently healthy eating.

Biscuit is any hard or crisp dry baked product made from cereals, apart from bread. They are ready to eat, convenient and inexpensive food products, containing digestive and dietary principles of vital importance (Omoba & Omogbemile, 2013; Omoba & Isah, 2018). Omoba & Omogbemile (2013) studied the suitability of sorghum – defatted soy flour blends in the production of biscuits with improved nutritional characteristics. The increment observed in the protein and mineral composition of the biscuits met the daily dietary requirement, especially for children.

The increasing consumers' demand for healthy foods with well-balanced nutritional profile and functional properties stimulates research on innovation in biscuits making. The conventional process for biscuits production does not include fermentation. However, novel recipes, including sourdough-fermented ingredients, were developed by Omoba et al. (2015a); Omoba & Isah (2018), aimed at enhancing the nutritional and functional properties of biscuits and enriching commercially available products with new sensorial profiles. Apart from improving the sensory properties, sourdough impedes starch digestibility; resulting in low glycemic response. It equally controls the levels and bioaccessibility of bioactive compounds and increase mineral bioavailability (Ganzel, 2014; Omoba & Isah 2018). Fermentation of cereals also produces non – digestible polysaccharides or causes modification of the cereal fibre complex to gut microbiota. Omoba et al. (2015a) reported on the sensory and nutritive profiles of biscuits from whole grain sorghum and pearl millet plus soya flour with and without sourdough fermentation. Descriptive sensory profiling revealed that sourdough biscuits were indistinguishable from a whole grain wheat biscuit standard in terms of hardness, roughness and coarseness, but they were darker, less crisp, less dry and denser with distinctive sorghum flavor **(Figure 5)**. According to our findings, two sorghum sourdough biscuits per day will, on average, contribute 13% of the Dietary Reference Intake of fibre for children aged 4–8 years. The sourdough biscuits produced had 10 – 17 % less phytate and phenolic contents with increased antioxidant activities.



(scores) with loading coordinates for sensory properties. Whole grain wheat (commercial reference biscuit), ar, aroma; fl, flavour; aft, aftertaste.

In the same vein, Omoba and Isah (2018) showed that the use of sourdough fermentation in biscuit production caused significant increase in the free amino acids, attributed to proteolysis caused by the flour enzymes, lactic acid bacteria (LAB) as well as the microbial enzymes in the flour. The increase in the free amino acids, was shown by the higher values observed in the amounts of specific amino acids (basic amino acids, sulphur - containing amino acids, aromatic amino acids and hydrophobic amino acids) in biscuits with sourdough (BWS) compared to biscuits without sourdough (BWOS) as shown on **Table 2.** Aromatic amino acids (tryptophan and phenylalanine) have the ability to give protons easily to electron deficient radicals while maintaining their stabilities via resonance structures (Guo *et al.,* 2009). Sulphur – containing amino acids (methionine and cysteine) have the capacity to offer their sulphur hydrogen; hence, these amino acids are considered effective free radical scavengers. Lactic acid bacteria have the capacity to synthesize antioxidant peptides during the sourdough fermentation of cereal flours. **Table 3** shows the bioactive phenolic compounds identified and quantified in the sourdough biscuit using Gas Chromatography - Mass Spectrometer (GC - MS). These are hydroxybenzoic, hydroxycimmanic, flavonols, ferulic acid, chlorogenic acid and quercetin, with BWS having the highest values.

Table 2: Amino acid composition (mg/g protein) of sorghum biscuits with and without sourdough

Amino acids	BWOS	BWS	Amino acid reference FAO/WHO/UNU
Cystine	13.30	13.30	
Methionine	15.50	17.10	25 (26)
Tyrosine	24.10	27.50	
Phenylalanine	40.80	42.60	47 (46)
Threonine	25.50	30.00	27 (27)
Valine	38.00	40.30	32 (42)
Leucine	56.90	60.40	55 (61)
Lysine	32.10	33.40	51 (52)
Isoleucine	28.50	30.80	25 (31)
Tryptophan	8.00	8.40	7 (7.4)
Aspartic acid	102.00	106.70	
Alanine	31.90	34.10	
Glutamic acid	163.50	168.10	
Glycine	46.60	48.00	
Proline	34.50	36.60	
Serine	35.40	41.60	
Arginine	75.70	78.30	
Histidine	21.70	23.00	
Total essential amino acid (TEAA)	189.00	203.30	287 (312.4)
Total non essential amino acid (TNEAA)	511.30	536.40	
Total amino acid (TAA)	700.30	739.70	
TEAA/TAA	0.27	0.28	
Hydrophobic amino acid	267.40	283.60	
Aromatic amino acid	94.60	101.50	
Acidic amino acid	265.50	274.80	
Sulphur-containing amino acid	28.80	30.40	

BWOS - Biscuit without sourdough; BWS - Biscuit with sourdough; Aromatic amino acids - phenylalanine, tryptophan, histidine, and tyrosine; Acidic amino acid - aspartic acid and glutamic acid.

Table 3: The phenolic profile (μg/mL) of sorghum with and without sourdough

Samples	BWOS	BWS
Hydroxybenzoic	19.65±0.10[a]	12.57±0.49[b]
Hydroxycinnamic	36.36±0.05[a]	26.66±0.45[b]
Flavanols	49.36±0.10[a]	42.54±0.10[b]
Ferulic acid	228.00±0.10[a]	203.00±0.10[b]
Chlorogenic acid	57.43±0.01[a]	34.45±0.02[b]
Quercetin	23.36±0.10[a]	10.26±0.10[b]

BWOS, biscuit without sourdough; BWS, biscuit with sourdough.
Mean±standard deviation of triplicate.
Mean values with the same letters (a,b) within the same row differ significantly (P<0.05).

These compounds are valuable sources of health – promoting bioactive phenolic. The total phenolic and flavonoid contents as well as antioxidant properties of biscuits revealed the superiority of BWS over BWOS and in some cases over the commercial biscuits (**Table 4**). The regular consumption of sourdough sorghum biscuits could therefore be considered as a healthy eating with beneficial effect on human health as it prevents PEM and assists in the management of degenerative diseases especially those resulting from antioxidant imbalance.

Table 4: Antioxidant properties of sorghum biscuits without and with sourdough

Sample	TPC (mg GAE/g)	TFC (mg QE/g)	FRAP (mg AAE/g)	ABTS (μmol/TE/100 g)	DPPH (mg/mL)	NO (mg/mL)
Commercial biscuit	2.32±0.09[c]	3.00±0.40[c]	0.79±0.30[b]	54.63±0.45[b]	88.76±0.34[a]	18.75±0.24[a]
BWOS	3.62±0.17[b]	3.46±0.13[b]	0.78±0.44[c]	42.01±0.25[c]	63.23±0.16[c]	14.58±0.44[c]
BWS	4.38±0.18[a]	4.75±0.21[a]	0.82±0.60[a]	60.31±0.42[a]	86.36±0.12[b]	16.66±0.43[b]

BWOS, biscuit without sourdough; BWS, biscuit with sourdough.
TPC, total phenol content; GAE, gallic acid equivalents; TFC, total flavonoid content; QE, quercetin equivalents; FRAP, ferric reducing antioxidant properties; AAE, ascorbic acid equivalent; ABTS, 2,2′-azino-bis(3-ethylbenzothiazoline-6-sulphonic) scavenging ability; TE, Trolox equivalents; DPPH, 1,1-diphenyl-2-picryl-hydrazy scavenging ability; NO, nitric oxide scavenging ability.
Mean±standard deviation of triplicate.
Mean values with the same letters (a-c) within the same column differ significantly (P<0.05).

3.1.3. Pearl millet (*Pennisetum glaucum* (L.) R. Br.)

Pearl millet belongs to the Family Gramineae and is quantitatively the most important millet, with world annual production ~14 million tonnes (Mt). Pearl millet is the sixth most important cereal annually cultivated as rain fed crop in arid and semi-arid areas of Africa and the Indian sub-continent (Fasasi, 2009a; Izge & Song, 2013; Omoba *et al.,* 2015a). It is cultivated mainly in the semiarid tropics; almost exclusively by subsistence and small-scale commercial farmers. In Nigeria, it is known as *jero* in northern Nigeria where it is often the main component of many meals and consumed as steamed – cooked products (couscous), thick porridges (*To*) and thin porridges (*ogi*), which can be used as complementary food for infants and young children and is also used in brewing beer. Pearl millet is nutritionally better than most other cereals; it has high level of calcium, iron, zinc, lipids and high quality protein.

In comparison to maize, pearl millet is 40% richer in methionine and lysine. Despite all these, studies have revealed that bioaccessibility of iron and zinc in pearl millet diet is very low due to the presence of inhibitors such as phytic acid, polyphenols, and fibres (Eyzaguirre *et al.,* 2006). Fasasi (2009b) therefore investigated the effect of some processing methods on the proximate, antinutritional compositions and functional properties of pearl millet and its applicability in the food systems. Roasting significantly reduced the inhibitors/antinutritional factors in pearl millet and thereby increased the bioaccessibility of iron and zinc when consumed. Zinc boosts the immune system; it is important in insulin action and carbohydrate metabolism.

In another study, Omoba et al.(2015a; 2015b) and Obafaye and Omoba (2018) harnessed the rich antioxidant properties of pearl millet (PM) in the development of biscuits. In pearl millet – tiger nut (*Cyperus esculentus*) flour biscuits, Omoba et al. (2015b) revealed increase in total phenolic contents (TPC) and 2,2'-azino-bis(3-ethylbenzothiazoline-6-sulphonic acid) (ABTS) radical scavenging abilities with increasing inclusion of pearl millet (Table 5).This was attributed to the high phenolic contents of PM (Fasasi, 2009b). Baking pearl millet dough into biscuits decreased the phenolic content and antioxidant activity due to heat-induced changes phenolic compounds **(Table 5).** The antioxidant potentials of the pearl millet –tiger nut (PM–TN) biscuits under physiological conditions was mimicked using gastrointestinal enzyme digestion in addition to the conventional aqueous, and organic solvent (ethanol) extracts. **Figure 6** revealed that higher TPC was released in the biscuits digested with two gastrointestinal enzymes (pepsin and pancreatin). The highest amount of total phenolics found in enzymatically digested biscuits might be due to the effect of hydrolysis. Cereal phenolic compounds in free, esterified and insoluble-bound forms, and insoluble-bound phenolics may be liberated by base, acid or enzymatic treatment of samples prior to extraction (Choi *et al.*, 2007).

Table 5: Effects of TN flour inclusion to PM flour on the total phenolic content, radical cation ABTS scavenging capacity of PM-TN flour and biscuits

	Total phenolic content (mgGAE/g)		ABTS (μmolTEAC/g)	
Samples	Flours	Biscuits	Flours	Biscuits
A	2.65 ± 0.01^{fA}	1.20 ± 0.01^{gB}	26.7 ± 0.01^{fB}	28.5 ± 0.00^{gA}
B	2.75 ± 0.03^{eA}	1.26 ± 0.03^{fB}	27.5 ± 0.01^{eB}	30.8 ± 0.01^{fA}
C	2.78 ± 0.02^{eA}	1.36 ± 0.01^{eB}	27.8 ± 0.01^{dB}	31.7 ± 0.02^{eA}
D	2.97 ± 0.01^{dA}	1.98 ± 0.01^{dA}	27.9 ± 0.01^{dB}	32.5 ± 0.01^{dA}
E	3.17 ± 0.02^{cA}	2.88 ± 0.03^{cB}	29.2 ± 0.00^{cB}	35.2 ± 0.03^{cA}
F	4.79 ± 0.04^{bA}	3.13 ± 0.01^{bB}	31.0 ± 0.01^{bB}	35.7 ± 0.01^{bA}
G	4.95 ± 0.01^{aA}	3.42 ± 0.01^{aB}	36.4 ± 0.01^{aB}	38.6 ± 0.01^{aA}

Notes: [a] Values are means of triplicates results ± SD; [b] values with different small letters (a-g) in the same column are significantly different at $p \leq 0.05$; [c] values with different capital letters (A-B) on the same row are significantly different at $p \leq 0.05$; keys: A PM15: TN 85; B PM20:TN80; C PM25: TN75; D PM30: TN 70; E PM35:TN 65; F PM40: TN60; G PM45:TN55

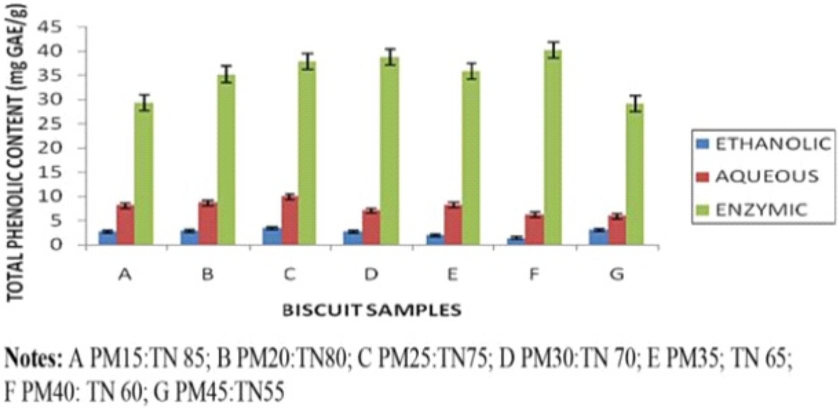


Figure 6: TPC, expressed as GAEs, as determined from biscuit matrix (100 g) using ethanolic extraction, aqueous extraction and after simulated gastrointestinal digestion. Data shown represent means ± SD (n=3 independent experiments)

3.1.4. Amaranth (*Amaranthus cruentus*)

The seed of Amaranth, known as e*fo tete* in Yoruba is an underutilized pseudo-cereal. Esan *et al*. (2018a) studied the biochemical and nutritional composition of two accessions of *A. cruentus* (PI538319 and PI538326). The two accessions showed high protein values of 15.5 and 16.1%, while the values of essential amino acids were 32.84 and 32.90 g/100g, respectively. Lysine, which is deficient in most cereals, was relatively high with values of 3.50 and 3.71 g/100g respectively **(Table 6).** The percentage ratio of the essential to nonessential amino acids was 42 – 45%. With reference to the WHO/FAO/UNU (2007) standard, the chemical scores showed that most of the essential amino acids in the two accessions of *A. cruentus* were present in high amounts when compared with other grain sources. Thus, the seed flour can fulfill the protein requirements of an adult human. In the same study, *A. cruentus* accession code PI538319 and PI538326 were deficient in sulphur containing amino acids and excess in aromatic amino acids.

Table 6: Amino acid composition of two accessions of *Amaranthus cruetus* (PI538319 & PI538326) (g/100 g)

Amino acid	PI538319	PI538326
Threonine*	3.49	3.19
Tyrosine*	2.23	2.23
Methionine*	0.75	0.80
Valine*	3.27	3.33
Phenylalanine*	3.01	3.19
Isoleucine*	2.55	2.09
Leucine*	4.96	5.19
Lysine*	3.55	3.71
Cysteine*	0.78	0.84
Histidine*	2.04	2.20
Tryptophan*	1.05	0.97
Arginine*	5.16	5.16
Aspartic acid	8.25	8.31
Glutamic acid	9.31	10.52
Serine	3.10	3.54
Proline	2.64	2.84
Glycine	3.37	3.46
Alanine	3.33	3.49

*Essential Amino Acids.

Aromatic amino acids serve as precursors for the synthesis of many biologically/neurologically active compounds that are essential for maintaining normal biological functions. In view of the presence of the high aromatic amino acids in amaranth, Esan *et al.* (2019) hydrolysed *A. cruentus* PI538326 and *A. caudatus*. The amino acids composition of the seed flours, protein isolate and hydrolysate revealed glutamic acid and aspartic acid as the most abundant amino acids. Lysine, the essential amino acid, limiting in cereals is readily available in the seed flour and hydrolyzed samples. This implies that the hydrolyzed samples might be supplemented with cereals for the production of healthy food for optimal health and wellbeing.

The protein quality evaluated, also showed isoleucine and sulphur containing amino acids as first and second limiting amino acids in *PI538326* and *PI595951* seed flours; and in protein isolate are sulphur amino acids; while the protein hydrolysate are all in excess of sulphur amino acids when compared with the WHO/FAO/UNU (2007) standard. The seed flours, protein isolate and hydrolysate contained adequate essential amino acids required by growing school children and adults; they could also be used as protein supplement in cereal based complementary diets.

Popping is a simple, inexpensive processing method which improves textural, sensory qualities of cereals with minimum changes in nutrient composition of the processed product. Esan *et al*., 2018b, popped (190 ± 10°C for 10sec) *A. cruentus* (PI538326)) seed flour (PAF) and compared the chemical compositions, functional and antioxidant properties with the raw seed flour (RAF). Significant increase was observed in the protein content of popped sample while, raw sample showed better ability in scavenging the free radicals compared to the popped. The study further established the consumption of RAF and PAF as healthy eating in a food system that is sustainable.

Omoba et al. (2021b) developed an extruded snack from blends of amaranth, shallot bulbs and soy bean flours. Hematological properties of *diabetes-induced* rats fed on formulated extruded snack and control sample were evaluated. High PCV (Packed Cells Volume) and Hb(Haemoglobin) levels obtained in rats fed with formulated extruded snacks established the high protein quality of the amaranth earlier reported by Esan *et al.* (2018a). Thus, suggesting that the components of the snack especially amaranth have capacity to synthesize blood cells, which further confirms the consumption of the snack as healthy eating, in the management of anemia.

3.2. Exploration of Legumes in Healthy Eating in the Control of NCDs

Dietary shift towards eating more plant-based food is identified as a key instrument to tackle dietary related diseases. Legumes belong to the Family Fabaceae*,* which include crops grown for seed (e.g., dry beans, dry peas and lentils), fresh vegetables (e.g., green beans and green peas) and livestock forage (e.g., clove and alfalfa). The protein content of legumes is up to threefold higher than in cereals. Moreover, legumes contain high amounts of lysine, which is low in cereals, and therefore legume protein could favorably complement cereal protein. In contrast to meat and meat products, legumes are also rich in dietary fibre, unsaturated fatty acids and the essential nutrient folate. In the past two decades I have worked on dry beans as healthy diets and these include; African yam bean, Bambara, Pigeon pea and *Dioclea reflexa* (*Agbaarin*).

3.2.1. African yam bean (*Sphenostylis stenocarpa*)

African yam bean known as *Sese* (Yoruba), *Nsana* (Ibibio) and *Girigiri* (Hausa), is a hard-to-cook underexploited legume grown extensively in Western Africa (Fasasi *et al.,* 2012; Esan & Fasasi, 2013). Though rich in nutrients, it is still largely underexploited, nutritionally; the seed is rich in protein, dietary fibre, carbohydrate and some valuable minerals (Anya & Ozung, 2019). Fasasi et al., (2012) studied the antioxidant properties of African yam bean hydrolysates (AYH) produced at different enzyme to substrate (E/S) ratios of 1: 100 and 3: 100 (W/V) using pepsin at pH 2.0 and 37°C. The usage of higher enzyme to substrate ratio reduced the antioxidant activities of the hydrolysates, hence reducing its potential health benefits. Esan & Fasasi (2013) produced African yam bean hydrolysate (42% degree of hydrolysis) using pancreatin. The amino acid compositions of the hydrolysate and its ability to scavenge free radicals were evaluated. The major amino acids found in the hydrolysate were glutamate, aspartate and arginine, while the sulphur-containing amino acids (methionine and cysteine) contents were very low (1.33g/0.83g and 1.32g/0.51g). The high degree of hydrolysis assisted in breaking down the proteins into lower molecular weight peptides (albumins) which yielded excellent scavenging properties with 2, 2-diphenyl-1-picryhydrazyl (DPPH).

3.2.2. Bambara Groundnut (*Vigna subterranea* (L.) Verdc.)

Bambara groundnut is an indigenous African legume, where it is the third most important legume in terms of consumption. It is locally called *ọkpa* in Igbo, *epa-roro* in Yoruba and *kwaruru* or *gurjiya* in Hausa. It has been termed a complete food, because its seed consist of 49%–63.5% carbohydrate, 15%–25% protein, 4.5%–7.4% fat, 5.2%–6.4% fiber, 3.2%–4.4% ash. Owing to its high nutrient content especially the protein content, Fasasi et al., (2009) produced protein isolate of 90% protein content from Bambara groundnut with good functionality, hence a good potential for application in food system. The consumption of “Bambara isolate - *ogi*" mix developed as complimentary diet is a healthy eating especially, in weight loss program.

3.2.3. Pigeon pea (*Cajanus cajan* (L.) Huth)

Pigeon pea is one of the most common tropical and subtropical legumes cultivated for its edible seeds. Pigeon pea is fast growing, hardy, widely adaptable, and drought resistant (Fasasi, 2012; Olagunju et al., 2018a, 2018b). Because of its drought resistance, it is considered of utmost importance for food security in regions where rainfall is unreliable and droughts are prone to occur. In Nigeria, it is called *fio fio* (Igbo), *waken-masar* or *waken-turawa* (Hausa), and *otili or otinli* (Yoruba). Pigeon pea, though underutilized, possesses relatively high protein content (~24%). Fasasi et al. (2012) discovered that the best haematological parameters were obtained for rats fed with the blends of wheat and pigeon pea, than for the control (wheat flour).

Similarly, Olagunju et al. (2018a) investigated the antioxidant properties; ACE/renin inhibitory activities of pigeon pea hydrolysates and the effects on systolic blood pressure of spontaneously hypertensive rats. The hydrolysates had high hydrophobic amino acids (HAA) and aromatic amino acids (AAA) **(Table 7).** As shown in **Figure 7**, pepsin-pancreatin- hydrolyzed pea protein (PPHPp) showed significantly higher ability to scavenge DPPH,˙while pancreatin-hydrolyzed pea protein (PPHPa) had higher ˙OH, ABTS+ scavenging, Fe3+ reducing and linoleic acid peroxidation inhibition. PPHPp exhibited superior angiotensin-converting enzyme inhibition (61.82%) while PPHPa showed higher renin inhibition (14.28%). PPHPp exhibited strong antihypertensive effect, showing an instantaneous systolic blood pressure lowering effect (−26.12 mmHg) within 2-h post- oral administration.

Table 7: Amino acid composition of pigeon pea isolate and hydrolysates

Composition (g/100 g)					
AA/samples	PPI	PPHPe	PPHPa	PPHPp	FAO/WHO (2007)
Aspartic acid	11.55	11.59	9.53	10.26	
Glutamic acid	20.06	19.90	22.50	21.41	
Serine	6.19	6.27	5.60	5.79	
Proline	4.83	5.02	5.04	5.06	
Glycine	3.12	3.63	3.54	3.61	
Alanine	4.00	4.04	3.82	3.86	
Arginine	6.91	6.95	7.57	7.36	
Valine	3.46	3.87	3.76	3.81	3.90
Methionine	0.97	0.90	0.75	0.82	1.60
Cysteine	0.43	0.60	0.59	0.60	0.60
Isoleucine	3.68	3.48	3.46	3.52	3.00
Leucine	8.37	8.09	6.88	7.34	5.90
Tyrosine	2.73	2.77	2.60	2.74	
Phenylalanine	8.58	7.38	6.80	7.37	3.80
Histidine	4.61	3.98	6.24	5.31	1.50
Threonine	3.27	3.93	3.43	3.66	2.30
Lysine	7.05	7.36	7.56	7.18	4.50
Tryptophan	0.20	0.25	0.32	0.30	0.60
HAA	37.24	36.38	34.02	35.42	
AAA	11.51	10.39	9.72	10.40	

Note - HAA: Hydrophobic Amino Acids; AAA: Aromatic Amino Acids; FAO: Food and Agriculture Organization; WHO: World Health Organization; PPI: Pigeon Pea Protein Isolates; PPHPe: Pepsin-hydrolyzed pigeon pea protein; PPHPa: Pancreatin-hydrolyzed pea protein; PPHPp: Pepsin-pancreatin-hydrolyzed pigeon pea protein.

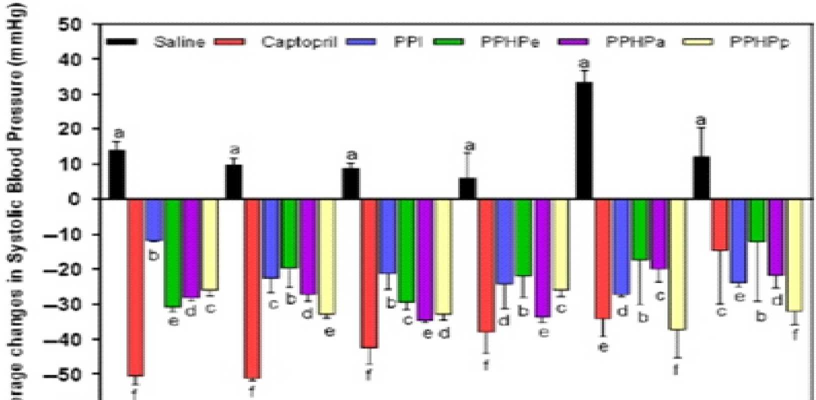


Figure 7: Average changes in systolic blood pressure of spontaneously hypertensive rats after oral administration of pigeon pea isolates and hydrolysates at 100 mg/kg body weight. Values are mean ± SD; Bars with different letters are significantly different (p<0.05). PPI: Pigeon Pea Protein Isolates; PPHPe: Pepsin-hydrolyzed pigeon pea protein; PPHPa: Pancreatin-hydrolyzed pea protein; PPHPp: Pepsin-pancreatin-hydrolyzed pigeon pea protein.

This was relative to the lowering effect (-50 mmHg) of captopril, a potent ACE inhibitor with recognized effect as antihypertensive agent. Pigeon pea protein hydrolysate (especially from pancreatin digest) could therefore, be a promising source of bioactive peptides and potential ingredient for formulation of functional foods against oxidative stress and hypertension. In the same study, Pigeon pea hydrolysates obtained using food grade enzymes (alcalase, pancreatin, pepsin + pancreatin) were fractionated by membrane ultrafiltration and evaluated for their antioxidant activities. Olagunju et al. (2018b) observed that fraction with molecular weight <1 kDa had the highest peptide yield (36.97%) for pepsin + pancreatin (PPHPp) hydrolysates, whereas fraction 1–3 kDa showed the highest yield (28.84%, 37.27%) for alcalase-derived peptide (PPHA) and pancreatin-derived peptide (PPHPa) respectively.

Low molecular weight fractions of PPHPa showed the highest inhibitory activity against DPPH, superoxide (PPHA, PPHPa), and OH scavenging activities. However, high molecular weight (MW) peptides exhibited better radical scavenging activity (DPPH) and reducing property (FRAP) than the low molecular weight peptides. All fractions exhibited higher ferric reducing and ABTS+ scavenging activities than the crude hydrolysates. All the peptides also had higher ABTS+ scavenging activity than glutathione (GSH). The low MW fractions (< 5 kDa) were able to inhibit the progression of lipid peroxidation during the first four days of incubation for most of the peptides.

Our findings (Olagunju *et al.,*2018b) showed that membrane ultrafiltration significantly increased antioxidant properties and the peptides exhibited the potential to be useful as functional ingredient in food and nutraceutical industry to maximise the use of underutilized protein sources. The consumption of food made from these peptides, especially PPHPa, could be referred to as healthy eating, to tackle the challenge of high blood pressure and its complications. Olagunju et al. (2020a) reported that thermoase-hydrolysed pigeon pea protein and its membrane fractions possess in vitro bioactive properties with antioxidative, antihypertensive, and antidiabetic properties.

Olagunju et al. (2018c) developed value-added nutritious crackers with high antidiabetic properties from blends of Acha (*Digitaria exilis*) and blanched pigeon pea *C. cajan*). The cracker biscuits had high protein contents especially with increased supplementation with pigeon pea flour. The anti - nutrient content of the formulated snack was low; hence may not adversely affect nutrient bioavailability. The biscuits exhibited good antioxidant properties; as indicated by its strong ability to scavenge hydroxyl, superoxide, DPPH radicals, and reduced Fe^{3+} to Fe^{2+}. The formulated crackers also possessed low glycemic index (47.95%) and significantly inhibited the key digestive enzymes (α-amylase and α-glucosidase). The consumption of the developed functional cracker in the management of hyperglycemia (diabetes) and prevention of associated degenerative diseases, could be denoted as healthy eating.

Legume starches have occupied important role in noodle and yoghurt production in several countries of the world, to reduce excessive burden on corn starch. Olagunju *et al* (2020b) studied the influence of acetylation on physicochemical and morphological characteristics of pigeon pea starch **(Figure 8 and Figure 9).** The physicochemical properties of the acetylated starches were significantly improved, demonstrating its potential usefulness as food additive. In a related study, Olagunju *et al*. (2020c) reported that acetylated pigeon pea starch possessed higher solubility and swelling power than native pigeon pea starch under the temperature regimes considered. Addition of acetylated pigeon pea starch as a stabilizer in yoghurt had positive influence on the water holding capacity compared to yoghurt stabilized with native pigeon pea starch **(Figure 10).**

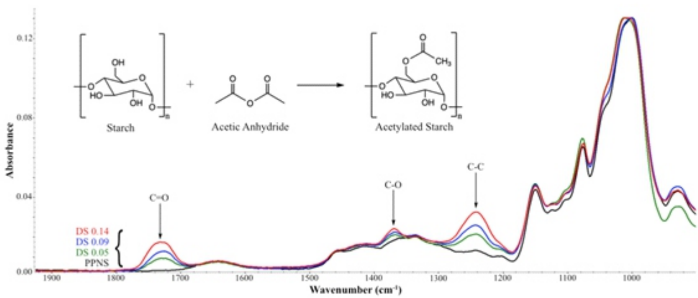
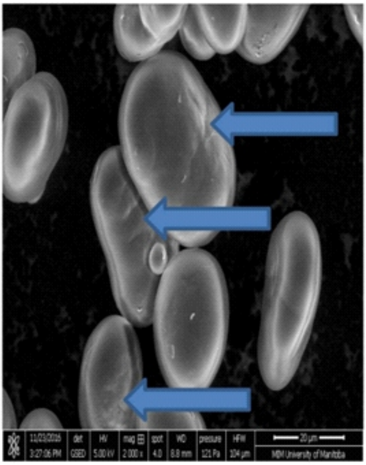
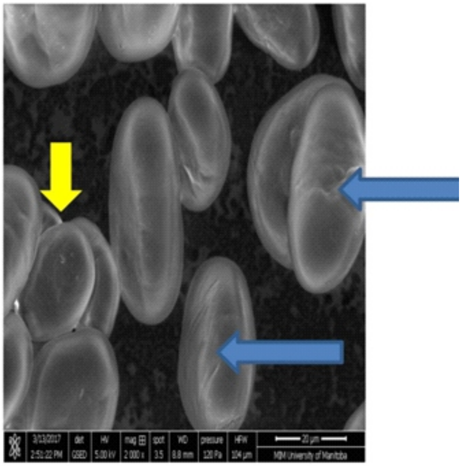


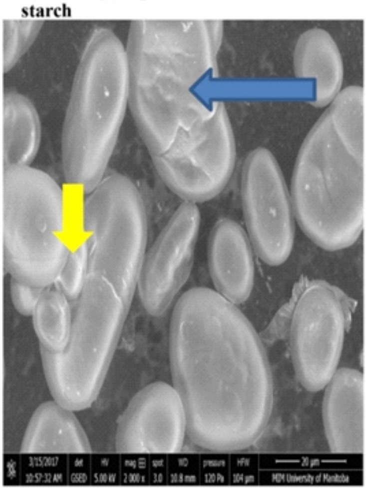
Figure 8: Three absorption bands in the FTIR spectra of acetylated pigeon pea native starch provide quantitative evidence of linearly increasing acetylation with increasing volumes of acetic anhydride treatment. Bands are assigned to functional groups introduced with acetylation. PPNS: Pigeon pea native starch; Pigeon pea acetylated starches with DS = 0.05, 0.09, 0.14.



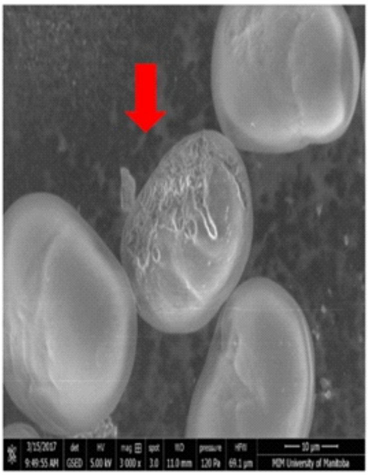
PPNS: Pigeon pea native starch



DS 0.05



DS 0.09`



DS 0.14

Figure 9: Scanning electron microscopy of native and acetylated pigeon pea starches. PPNS: Pigeon pea native starch; DS 0.05: Pigeon pea acetylated starch, level 1; DS: 0.09: Pigeon pea acetylated starch, level 2; DS 0.14: Pigeon pea acetylated starch, level 3.

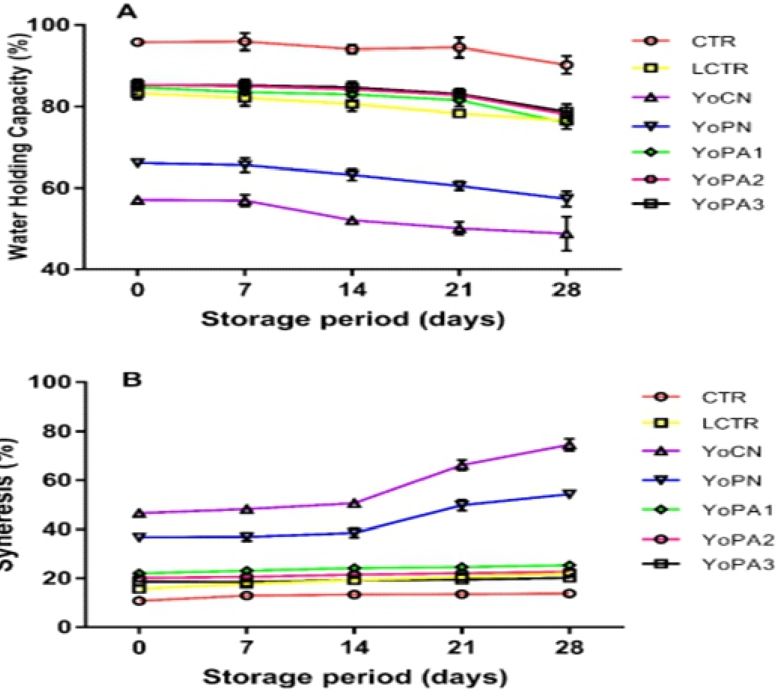


Figure 10 (A, B): Effect of refrigeration storage on water holding capacity and syneresis of yoghurt. CTR – Commercial yoghurt; LCTR – gelatin stabilized yoghurt; YoCN – yoghurt without stabilizer; YoPN – Yoghurt stabilized with native starch; YoPA1 – Yoghurt stabilized with DS 0.05 acetylated starch; YoPA2 – yoghurt with stabilized with DS 0.09 acetylated starch; YoPA3 – yoghurt stabilized with DS 0.14 acetylated starch.

3.2.4. Marble vine (*Dioclea reflexa*)

Marble vine is a grossly underutilized legume that belongs to the family Leguminosae and sub-family Papillionoideae (Akinyede *et al.,* 2017). Marble vine is also known as sea beans, horse eye, and *agbaarin* (Yoruba) and Ukpo and Ebba (Igbo). Ajatta *et al*. (2019, 2021a,b) assessed the optimum roasting conditions on the phytochemical properties of three varieties of marble vine seeds using Response Surface Methodology (RSM). The study showed that availability of phytochemical activities was heat-dependent. However, prolonged durations of roasting favoured increased amounts of total phenolic (TP) and total flavonoid (TF) contents in dark and light varieties. Total sterol, tannin, and cardiac glycoside contents increased with increasing roasting temperature and time. Marble vine seed flour, therefore holds the potential in the development of functional foods and in therapeutic applications to promote good health.

Ajatta *et al.* (2020), investigated the protective effect of formulated marble vine/plantain dough meals on cognitive impairment in diabetic rats. Rats fed with (High Fat Diet/Streptozotocin) HFD/STZ may develop signs of cognitive impairment as a result of oxidative stress incurred from increase in blood glucose level and acetylcholinestarase (AChE) activity. **Figure 11** revelaed the effects of formulated marble vine/ plantain dough meal supplemented diet on plasma glucose level in diabetic rats; the activities of the dough meal (DDP4), compared favourably with metformin. The formulated dough meal has neuroprotective potentials in preventing neurological complications arising from diabetes **(Figure 12 and Figure 13)** due to the release of bound phenols present in marble vine. Consumption of the marble vine/plantain doughmeal as a healthy diet in a sustainable food system is a healthy eating required in the management of hyperglycemia condition and its complications.

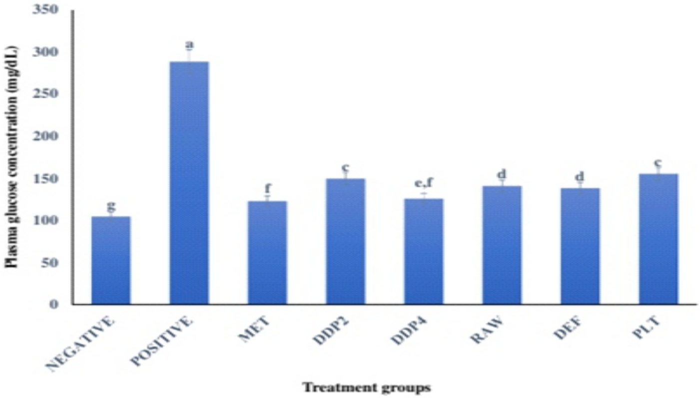


Figure 11: Effects of formulated marble vine/plantain dough meal supplemented diet on plasma glucose level in diabetic rats. Values are expressed as mean ± SEM (n=6). Bars with similar alphabet are not significantly different ($p<0.05$). Negative: control rats that received normal diet; Positive: diabetic rats (HFD/STZ induction alone); MET: HFD/STZ induction and metformin; DDP2: HFD/STZ induction and 20% defatted *D. reflexa* and 80% plantain dough meal; DDP4: HFD/STZ induction and 40% defatted *D. reflexa* and 60% plantain dough meal; RAW: HFD/STZ induced and raw un-defatted D. reflexa dough meal; DEF: HFD/STZ induction and 100% defatted *D. reflexa* dough meal; PLT: HFD/STZ induction and 100% plantain dough meal

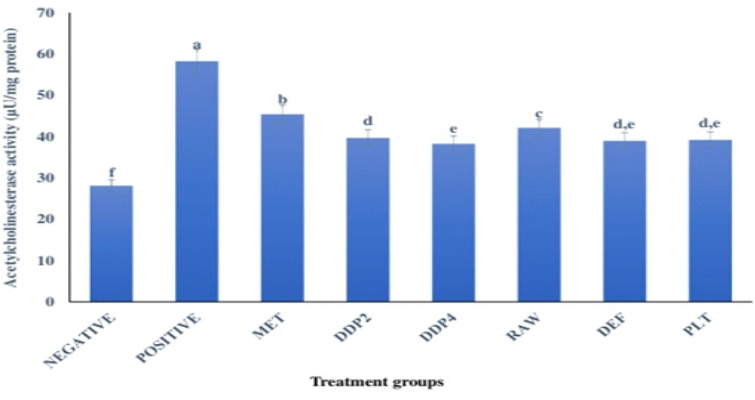


Figure 12: Effects of formulated marble vine/plantain dough meal supplemented diet on acetylcholinesterase activities in the brain of diabetic rats. Values are expressed as mean ± SEM (n=6). Bars with similar alphabet are not significantly different ($p<0.05$). Negative: control rats that received normal diet; Positive: diabetic rats (HFD/STZ induction alone); MET: HFD/STZ induction and metformin; DDP2: HFD/STZ induction and 20% defatted D. reflexa and 80% plantain dough meal; DDP4: HFD/STZ induction and 40% defatted *D. reflexa* and 60% plantain dough meal; RAW: HFD/STZ induced and raw un-defatted *D. reflexa* dough meal; DEF: HFD/STZ induction and 100% defatted *D. reflexa* dough meal; PLT: HFD/STZ induction and 100% plantain dough meal.

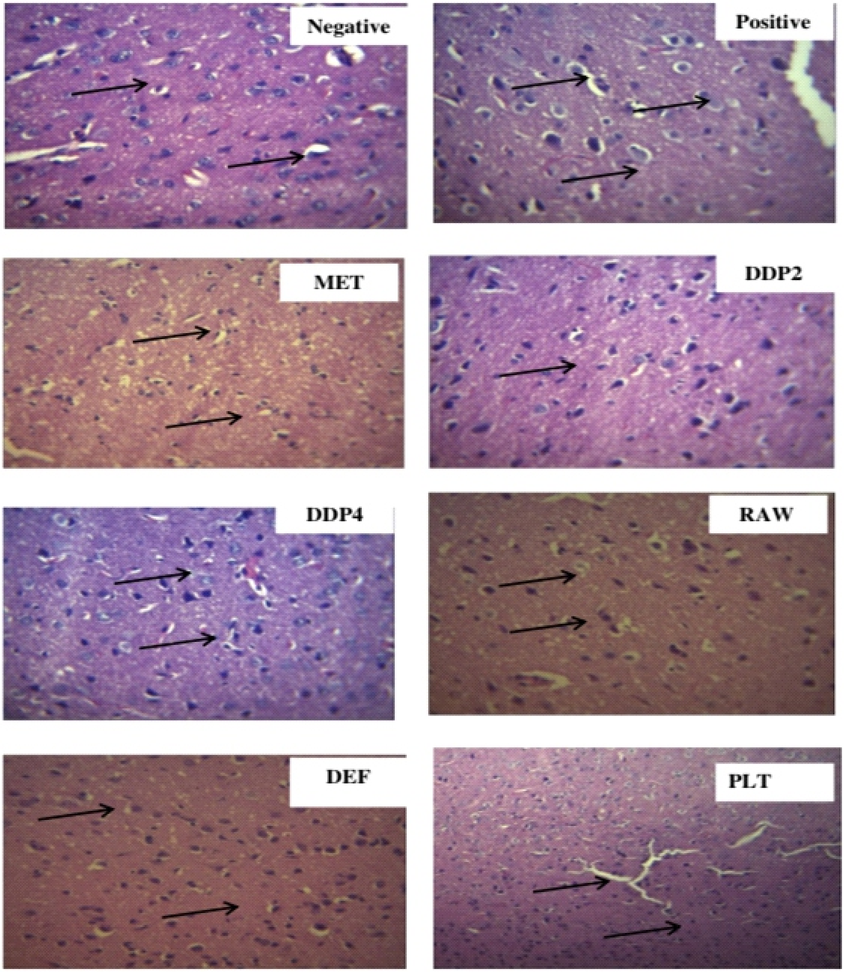


Figure 13: Representative photomicrographs showing hematoxylin and eosin stained sections of brain tissues of diabetic rats treated with formulated marble vine/plantain dough meal supplemented diet (400x). Negative: control rats that received normal diet; Positive: diabetic rats (HFD/STZ induction alone); MET: HFD/STZ induction and metformin; DDP2: HFD/STZ induction and 20% defatted *D. reflexa* and 80% plantain dough meal; DDP4: HFD/STZ induction and 40% defatted *D. reflexa* and 60% plantain dough meal; RAW: HFD/STZ induced and raw un-defatted *D. reflexa* dough meal; DEF: HFD/STZ induction and 100% defatted *D. reflexa* dough meal; PLT: HFD/STZ induction and 100% plantain dough meal.

Ajatta et al., 2021b also assessed the effect of roasting on the chemical composition, functional characterization and antioxidant activities of three varieties of marble vine (*Dioclea reflexa*). The study revealed that roasting at 110°C is suitable for the release of food nutrients and improve the functionality of marble vine seed flour. The changes occurring in the functional groups of marble vine seed variety was studied by FTIR spectroscopy and the spectral obtained is presented in Figures 14, 15, and 16. The broad and strong absorption bands observed at 3247cm^{-1} for the three seed variant of roasted marble vine seed floors indicates alcohol-phenol (-OH) groups (Gani, *et al.,* 2016). The O-H group reduces the activities of free radicals and could help reduce rancidity in foods. The roasted and unroasted varieties of marble vine seed floors showed an identical pattern of absorption bands which indicates the similarity of compounds present in each treatment.

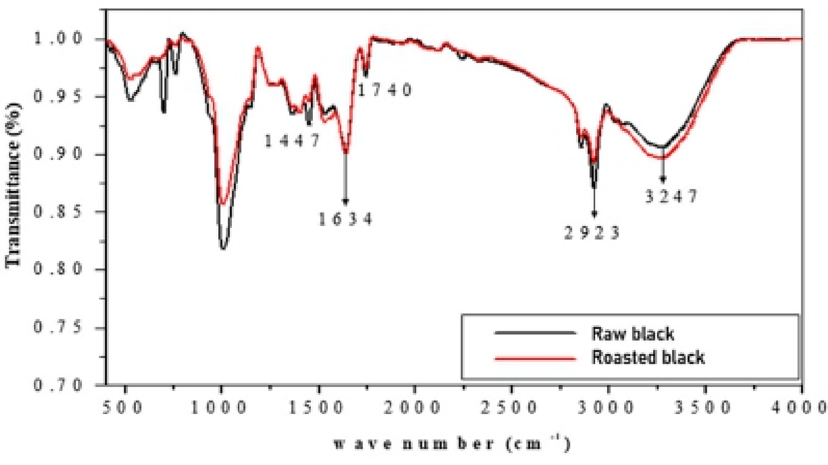


Figure 14: Spectral analysis obtained from FTIR for black *Dioclea reflexa seed.*

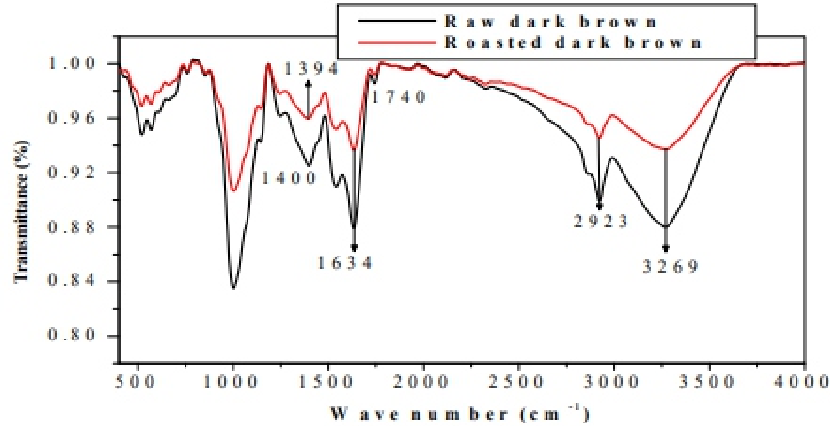


Figure 15: Spectral analysis obtained from FTIR for dark brown *Dioclea reflexa* seed.

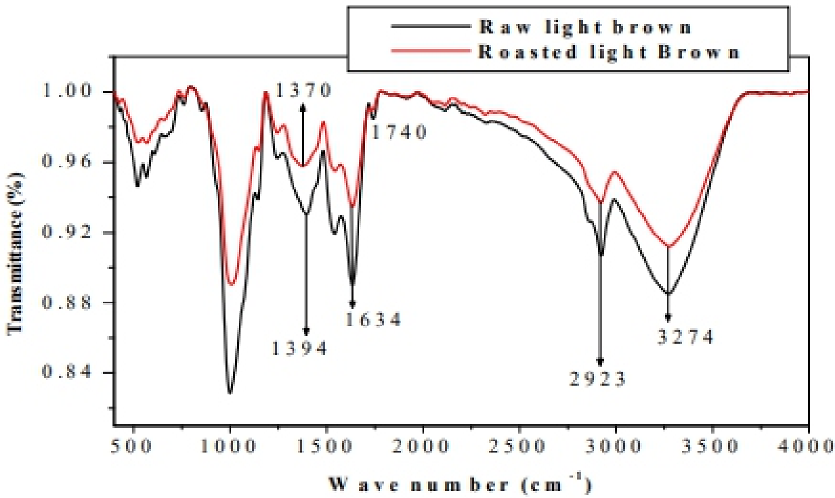


Figure 16: Spectral analysis obtained from FTIR for light brown *Dioclea reflexa* seed.

3.2.5. Cowpea (*Vigna unguiculata*)

Cowpea is one of the most important food legumes grown in the semi-arid tropics. Cowpea flours contain 25% protein, several vitamins and minerals, starch (35.0–52.0%) which has unique properties (i.e. low gelatinization temperature, freeze thaw stability) and serve as energy source for human nutrition (Tinus *et al.,* 2012). Also, cowpea contains a high amount of resistant starch and dietary fibre and can be considered a food of low glycemic index (GI). Fasasi and Karim (2011) developed a healthy noodle using cowpea starch. Alkaline noodle was prepared from blends of wheat flour and cowpea starch (2%, 4% and 6%). Noodles were assessed for total starch, resistant starch contents (TS and RS) and functional properties. Results revealed that the noodles produced from cowpea starch had higher TS and RS, with low GI compared to the control (wheat) noodle. The study confirmed the replacement of corn or cassava starch with cowpea starch as potential raw material in the production of noodle for healthy eating.

3.3 Roots and Tubers in Healthy Eating for Optimal Health and Wellbeing

Root and tuber crops are important cultivated staple energy sources and are second to cereals in the tropics. They include Irish potatoes (*Solanum tuberosum*), cassava (*Manihot esculenta*), sweet potatoes (*Ipomea batatas*), yams (*Dioscorea sp*), and other aroids. For over two decades, I researched on cassava, sweet potato, orange fleshed sweet potato as healthy diets.

3.3.1. Cassava (*Manihot esculenta*)

As wheat and potatoes are to farmers in Europe, so is cassava to the farmers in Africa. Cassava is a staple food and animal feed in tropical and subtropical Africa, Asia, and Latin America, with an estimated total cultivated area of over 13 million hectares, of which more than 70% is in Africa and Asia (Montagnac, *et al*., 2009). Cassava alone provides the major source of dietary calories for about 500 million people; many of them in Africa (Bayata, 2019). In areas where cassava is a main staple, people have developed ways for its processing into storable products such as tapioca, starch, dough and *gari*. It plays a major role in the efforts to alleviate the African food crisis because of its high yield, year round availability and tolerance to extreme stressful conditions. However, the nutritional value of cassava roots are low vis-à-vis minerals, vitamins, lipid, and protein contents. Fasasi *et al.* (2010); Omoba and Azeez (2016) produced high protein fermented cassava flour (*fufu* mix) and steamed/boiled blue whiting fish (*Micromesistius poutassou*) cracker. The high protein fermented cassava flour (*fufu* mix) was prepared from a blend of cassava flour (CF) and fish flour (FF) at ratio 5:1 obtained through linear programming Corel Quatro pro 18 with a target protein of 16% and fat content of 9%. Significant increase in the protein and amino acid contents of the improved fermented cassava flour (*fufu* mix) were observed. The abundant amino acids were arginine, glutamic acid, and methionine. The most abundant fatty acid was oleic acid. This study confirms the endless possibilities of protein enrichment of cassava flour with fish powder for the production of *fufu* as a potentially effective strategy for enhancing protein-energy-balance particularly in developing countries.

Omoba and Azeez (2016) developed blue whiting fish cracker using boiling and steaming methods. Minced blue whiting fish, known as Atlantic cod (*Gadus morhua*), was mixed with cassava starch at ratio 50:50 and other ingredients were incorporated, to obtain the non – expanded blue whiting fish cracker, which was further fried to obtain the expanded fish cracker. Results revealed that the proximate, mineral and amino acid compositions, and fatty acid profiles of the steamed blue whiting (fish) crackers were higher than values obtained for the boiled cracker samples. However, variations were observed in the microstructural properties of the crackers which were attributed to the complete gelatinization of starch in the boiled cracker compared to the steamed crackers. The consumption of blue whiting (fish) crackers as healthy snack might be recognized as healthy eating not only in solving the challenge of protein energy malnutrition but also applicable in weight loss management.

3.3.2. Orange Fleshed Sweet Potato (*Ipomea batatas L.)*

Vitamin A Deficiency (VAD) is a widespread nutritional problem amongst children in developing countries, including Nigeria, leading to impairment in growth, development, vision and poor immune functions (Rahman, *et al.,* 2013). Also, the prevalence of VAD in pregnant women had been implicated to increase the risk of maternal mortality (Faisel & Pittrof, 2000). The consumption of carotenoid-rich food is a healthy eating, feasible remedy to combat the deficiency (Omoba *et al.,* 2021a; Olagunju *et al.,* 2020d; Oloniyo *et al.,* 2020;

Ogunnowo *et al.,* 2021). Orange-fleshed sweet potato (OFSP) is an excellent source of natural health-promoting compounds such as β-carotene and anthocyanins; in addition, it possesses high dietary fibre and mineral content. It is often regarded as a potential food security crop owing to its easy cultivation, drought resistance, outstanding vitamins, minerals, dietary fibre and protein contents exceeding that of most staple crops (Mosta *et al.,* 2015).

Omoba *et al.* (2021a), developed cakes with significant carotenoid contents from OFSP **(Table 8)**. However, carotenoid contents obtained for cakes were lower (6.15–6.88 mg/100 g) compared with higher values in flour blends. The lower values of carotenoids observed in cakes were attributed to losses resulting from baking which has been associated with the characteristic low stability of carotenoid compound to light, oxygen and temperature (Fonseca *et al.,* 2008). However, the estimated β–carotenoid contents of the cakes ranged from 49 to 55 µg/g, giving approximately 211 to 236 µg RAE (Retinol Activity Equivalent) for a single serving of the cake (1 serving = 60 g). The total carotenoid contents of cake, thus suggest that snack is a potential source of provitamin A, with four servings of the cake (844 µg RAE) meeting the recommended daily requirement of 700 to 1300 µg RAE/day for children and nursing mothers.

Table 8: Total carotenoid, β-carotenoid and vitamin A content of OFSP–TN composite flour and cake

Samples	Total carotenoid (mg/100 g)	β-carotenoid (µg/g)	Vitamin A (µg RAE)	Total RAE content (µgRAE) per serving
FLOURS				
A	12.85 ± 0.17[a]	102.8 ± 0.02[a]	7.34	
B	10.67 ± 0.21[b]	85.4 ± 0.03[b]	6.10	
C	9.75 ± 0.09 [c]	78.0 ± 0.03 [c]	5.57	
CAKES				
AC	6.88 ± 0.02[a]	55.1 ± 0.01[a]	3.93	235.8
BC	6.15 ± 0.03 [c]	49.2 ± 0.02[b]	3.51	210.6
CC	6.69 ± 0.02[b]	53.5 ± 0.02[a]	3.82	229.2

Results are mean ±SD of replicate data. Mean with different superscripts within the same column are significantly different ($p < 0.05$).
Conversion factor of β-carotene (a) to vitamin A (µgRAE) = 1:14.
A: 100% OFSP flour, B: 95:5% OFSP–TN flour blend, C: 90:10% OFSP–TN flour blend, AC: 100% OFSP cake, BC: 95:5% OFSP–TN cake, CC: 90:10% OFSP–TN cake.

Similarly, Oloniyo *et al.* (2020) developed Orange-fleshed sweet potatoes composite bread as a good carrier of β-carotene and antioxidant properties. The study assessed antioxidant activity, α–amylase, and α–glycosidase inhibitory activities, protein and β-carotene retention/losses, glycemic index as well as evaluate the sensory properties of the bread. OFSP composite bread had high antioxidant properties which could be attributed to its high β-carotene contents revealing the ability of the bread to scavenge free radicals. The bread samples gave low to medium estimated GI with values ranging from 51.42% to 61. 42%. The value of β-carotene before and after processing ranged from 15.4 to 39.1 mg/100 g (before) and 8.9 to 18.4 mg/100 g (after) processing (**Table 9)**; corroborating low stability of carotenoid compound to temperature. All the bread samples showed peak inhibitory effect on α-glucosidase than α–amylase (**Figure 14).** These insignificant inhibition of α-amylase and significant inhibition of α-glucosidase are of significant health importance in the treatment of degenerative diseases. Low to medium GI of the bread implies that, they are more slowly digested, absorbed and metabolized and caused lower and slower rise in blood glucose thus establishing its relevance in the management of hyperglycemia.

In Nigeria, the consumption and palatability of sweet potato is achieved by subjecting the tuber to different culinary practices such as boiling, roasting, frying and steaming. Many traditional household culinary practices can affect the bioavailability of nutrients in plant-based diets as our studies revealed; that processing significantly affect the carotenoid retention/loss (Omoba *et al.,* 2021a; Oloniyo *et al.,* 2020). Olagunju *et al.* (2020d) investigated the effect of the different culinary processing methods on the physicochemical, antioxidant properties and carotenoid retention/loss of culinary processed OFSP. The results showed that the different culinary processing methods significantly ($p \leq 0.05$) increased total phenolic content (TPC), total flavonoid (TF) and carotenoid contents (with the exception of fried; boiled without peels and roasted samples). Fried samples showed the highest carotenoid content (0.42 μg/g).

Table 9: Percentage losses of protein and β-carotene in sweet potato composite bread

Sample	Protein (%)	Carotenoid (mg/100 g)	Protein (%)	Carotenoid (mg/100 g)	Protein (%)	Carotenoid (%)
	Before processing		After processing		Percentage looses	
MDP	19.6 ± 0.7^{b}	39.1 ± 0.6^{a}	10.3 ± 0.1^{b}	18.4 ± 0.1^{a}	47.4 ± 0.2^{d}	52.9 ± 0.5^{c}
KJP	21.1 ± 0.3^{a}	20.7 ± 0.8^{d}	15 ± 0.4^{a}	8.2 ± 0.7^{d}	28.9 ± 0.4^{f}	60.4 ± 0.2^{a}
CFP	18.3 ± 0.5^{c}	13.2 ± 0.6^{f}	7.3 ± 0.2^{c}	8.1 ± 0.3^{d}	60.1 ± 0.4^{a}	38.6 ± 0.3^{e}
MDC	7.2 ± 0.2^{d}	36.5 ± 0.5^{b}	4.0 ± 0.3^{d}	14.6 ± 0.1^{b}	44.4 ± 0.7^{e}	60.0 ± 0.1^{a}
KJC	7.5 ± 0.1^{d}	26.2 ± 0.1^{c}	3.1 ± 0.1^{e}	11.1 ± 0.2^{c}	58.7 ± 0.6^{b}	57.6 ± 0.7^{b}
CFC	7.0 ± 0.3^{d}	15.4 ± 0.2^{e}	3.2 ± 0.1^{e}	8.9 ± 0.2^{d}	54.3 ± 0.3^{c}	42.2 ± 0.4^{d}

Note: Values are averages of triplicate readings (mean ± standard deviation). Means within a column followed by different superscript letter(s) are significantly differences ($p \leq .05$).
Key: MDP- SP:SC:DP:PS- 56:20:10:14; KJP- SP:SC:DP:PS- 56:20:10:14; CFP- SP:SC:DP:PS- 56:20:10:14; MDC- SP:SC:DP:PS- 70:06:10:14; KJCSP:SC:DP:PS- 70:06:10:14; CFC- SP:SC:DP:PS- 70:06:10:14; WHT- control. Abbreviations: CFP and CFC, cream-fleshed sweet potato; KJP and KJC, King -J orange fleshed sweet potatoes; MDP and MDC, mother's delight orange fleshed sweet potatoes; WHT, wheat

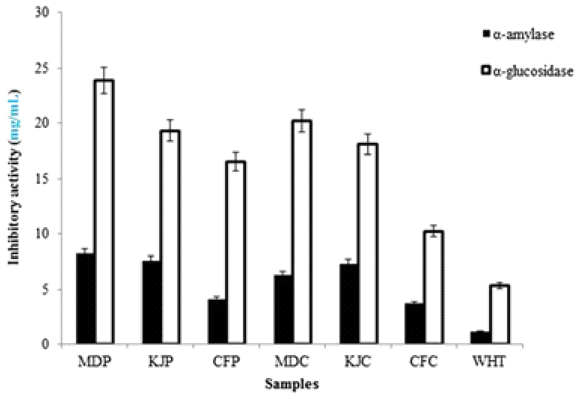


Figure 17: α-amylase and α-glucosidase inhibitory activity (mg/ml) of orange fleshed sweet potato composite bread. Key: MDPSP:SC:DP:PS- 56:20:10:14; KJP- SP:SC:DP:PS- 56:20:10:14; CFP- SP:SC:DP:PS- 56:20:10:14; MDC- SP:SC:DP:PS- 70:06:10:14; KJCSP:SC:DP:PS- 70:06:10:14; CFC- SP:SC:DP:PS- 70:06:10:14; WHT- control; CFP and CFC, cream fleshed sweet potato; KJP and KJC, King –J orange fleshed sweet potatoes; MDP and MDC, mother's delight orange fleshed sweet potatoes; WHT- wheat.

Significant reduction in anti - nutrient contents was observed in processed OFSP, with increased antioxidant activities. The increase in TPC, TF and carotenoid contents is due to the damaging effect of heat on the cell structures of sweet potato tubers resulting in easy extraction of antioxidant components (Tokusoglu & Yildirim, 2012) from the root itself or those from the peel diffusing to the root (Mokbel & Hashinaga, 2005). Leaving the potato tuber skin on the tuber prior to heat processing has contributed to the retention of nutraceuticals potentials. Thus, processing OFSP with peel gives product with optimal nutritional benefits.

Oloniyo *et al.* (2021) compared the biochemical and antioxidant properties of cream-fleshed (CFSP) and orange-fleshed sweet potato (OFSP) varieties. Results revealed that the antioxidants properties evaluated were higher in OFSP than CFSP.The bio-fortified sweet potato showed improved biochemical and antioxidant properties compared to the CFSP. Thus, OFSP would be suitable to combat micronutrient deficiency and food insecurity in Africa.

Ogunnowo *et al.* (2021), studied the effect of processing methods (Steaming {with or without peel}), roasting, boiling (with or without peel), and frying on the functional and pasting properties, colour (L* a* b*ΔE*), hydrolysis index (HI), estimated glycemic index (eGI) and glycemic load (GL). Processing methods reduced lighteness (L*), and increased the yellowness (b*) of the orange fleshed sweet potato (OFSP) flour while well -visible colour differences (ΔE*) were observed in processed samples compared to the control (RAW –OF and RAW – CF). Processing reduced the HI, eGI of OFSP, with roasted OFSP having the lowest eGI of 60 (medium GI). This information would therefore serve as a basis for dietary advice to subjects that require healthy eating with medium to low GI.

3.4. Application of Herbs and Spices in Healthy Eating for Optimal Health and Wellbeing

"Herbs" and "spices" describe plants or parts of plants used for medicine, cooking, and pleasure all over the world. Herbs are the green, leafy parts of plants; they are most effective and flavoursome when used fresh, and they are generally cultivated in temperate to tropical regions e.g., *Ocimum basilicum (Efinrin wewe)*. Spices are derived from any part of plant that is not a leaf: for example, cloves are flower buds, cinnamon is bark, ginger is a root, peppercorns are berries, nigella is seed, cumin is a fruit, saffron is stigma, cardamom pods and seeds, and asafetida is a gum. The constituents of herbs and spices have complementary and overlapping actions, including reduction of inflammation, antioxidant effects, modulation of detoxification enzymes, modulation of the immune system and antibacterial and antiviral effects.

A range of bioactive compounds in herbs and spices have been studied, by my research group over the two decades. Omoba *et al.* (2019) evaluated the methanolic extracts of *Ocimum basilicum*- OB (*Efinrin wewe*), *Xylopia aethiopica*- XA (*'Eeru', 'Uda', 'Chimba'*), and *Piper guineensis*- PG (*'iyere, 'uziza'*) for the profiling of their phenolic compounds and *in vitro* antioxidant properties. Results revealed that quercetin, quercitrin, and isoquer-citrin are the most prevalent phenolic compounds in OB, XA, and PG, respectively (**Figure 18**); these compounds are of significant health importance. XA showed the highest total phenolic and total flavonoid contents, as well as the highest DPPH, ABTS and nitric oxide scavenging activities

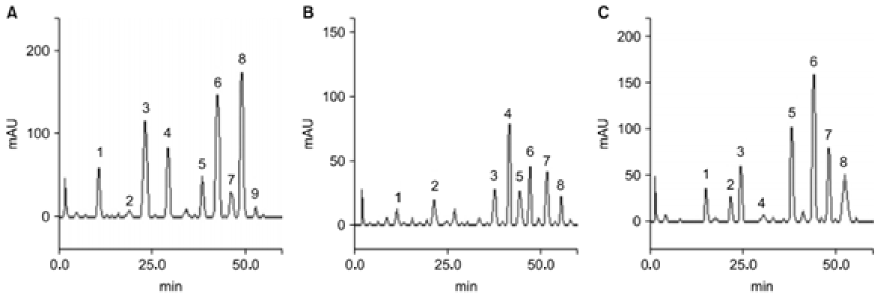


Figure 18: Representative high performance liquid chromatography profiles. (A) Extract of *Ocimum basilicum*: peak 1, gallic acid; peak 2, chlorogenic acid; peak 3, caffeic acid; peak 4, rosmarinic acid; peak 5, rutin; peak 6, isoquercitrin; peak 7, quercitrin; peak 8, quercetin; peak 9, kaempferol. (B) Extract of *Piper guineensis*: peak 1, gallic acid; peak 2, chlorogenic acid; peak 3, rutin; peak 4, isoquercitrin; peak 5, quercitrin; peak 6, quercetin; peak 7, dihydrocapsaicin; peak 8, capsaicin. (C) Extract of *Xylopia aethiopica*: peak 1, xylopic acid; peak 2, chlorogenic acid; peak 3, caffeic acid; peak 4, ellagic acid; peak 5, rutin; peak 6, quercitrin; peak 7, quercetin; peak 8, kaempferol.

Thus, the XA methanolic extract demonstrated a high content of phenolic compounds and significant antioxidative properties with prospective potency to prevent oxidative damage and promote better cardiovascular health.

In a similar study, Ifesan, *et al.* (2011) studied the physicochemical properties of two spices, turmeric (*Curcuma longa)* and ginger (*Zingiber officinale)* and the antioxidant activities of their oils. Results revealed that oils extracted from *Z. officinale* and *C. longa* could be good sources of antioxidants in diets since they are locally available. Ifesan *et al.* (2012) also produced bread - spread from blends of shea butter (*Vitellaria paradoxa*), garlic (*Allium sativum*), ginger (*Zingiber officinale*), scent leaf (*Occimum gratissimum*) and *suya* spice. Addition of spices to shea butter increased the ability of the blends to scavenge free radical, resulting in healthy bread – spread with improved shelf life.

The consumption of tea (C*amellia sinensis*) flavonoids has been associated with reduced incidences of cardiovascular disease and cancer. Makanjuola *et al.,* (2015a, b) applied Response Surface Methodology (RSM) and multivariate statistics in predicting the antioxidant property of ethanolic extracts of tea – ginger blend. Results from the multi-response optimization revealed the optimum conditions for the extraction of tea – ginger blend, as temperature of 50.16°C, concentration of 2.1 g $(100\ ml)^{-1}$ and time of 5 minutes with a desirability of 0.68. The study also revealed that, colour and hue index properties gave an indication of some antioxidant properties of ethanolic extracts of tea-ginger blend.

In the same vein, Makanjuola *et al.* (2015c; 2016; 2020) investigated the effects of temperature, concentration, and time on the antioxidant properties of aqueous extract of tea-ginger (2:1) powder. **Table 11,** shows the response surface models and comparative analysis regression techniques for antioxidant prediction for ethanolic extracts, respectively. **Figure 19** revealed the response surface graphs showing effect of extraction variables on antioxidant properties (A), total flavonoid content (B), total phenol content (C), ABTS (D), and peroxide scavenging activity; during aqueous extraction of tea-ginger powder.

Table 11: Response surface model for aqueous extraction of tea-ginger 2:1 powder

Source	Total flavonoid content (mg CE/L)	Total phenol content (mg GAE/L)	ABTS (mg TE/L)	Peroxide scavenging activity (%)	Iron chelating activity (%)	DPPH (%)
Transformation	Sqrt(TF)	Log_{10}(TP)				
INTERCEPT	−3.3900	2.5773	0.7858	36.9479	89.1034	11.1457
TEM	1.1710	1.7622E-3				
CON	11.0702	0.6350	0.05296	31.1367		
TIM	0.4244		4.2216E-3	−0.75464		
TEM*CON	0.2970					
TEM*TIM						
CON*TIM			−1.063E-3			
TEM^2	−9.4820E-3					
CON^2		−0.1726		−12.1169		
TIM^2	−4.2766E-3		−2.534E-5	8.5620E-3		
Model (*p*-value)	<0.0001	<0.0001	0.0023	0.0091		
Lack of Fit	0.4347	0.6804	0.2478	0.9832	0.5713	0.8670
R^2	0.9639	0.8873	0.6485	0.5721	0	0
Adj R^2	0.9472	0.8662	0.5547	0.4580	0	0
Pred R^2	0.9018	0.8106	0.1755	0.3273		
Adeq Precision	23.406	17.274	8.203	9.464		

TEM, temperature; CON, concentration; TIM, time; Adj R^2, adjusted R^2; Pred R^2, predicted R^2; Adeq Precision, adequate precision; Sqrt(TF), square root of total flavonoid; Log_{10}(TP), Log of total phenol.

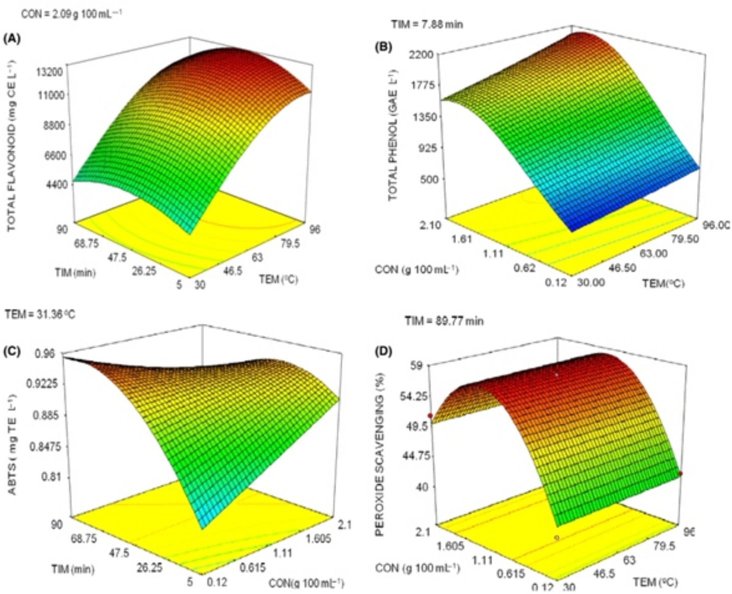


Figure 19: Response surface graphs showing effect of extraction variables on antioxidant properties (A), total flavonoid content (B), total phenol content (C), ABTS (D), and peroxide scavenging activity; during aqueous extraction of tea-ginger powder.

Ademosun *et al.* (2021) developed ginger based fruit drinks (from blends of ginger, pineapple and apple). Ginger based fruit drinks exhibited high phenolic distribution, high DPPH●+, ABTS●+ scavenging abilities as well as FRAP. All the ginger based drinks exhibited low glycemic indices **(Table 12)**. The drinks showed strong inhibition against carbohydrate hydrolyzing enzymes; α-amylase and α-glucosidase (**Figures 20 & 21**) and may be suitable for the control of hyperglycemia and some degenerative conditions linked with oxidative stress.

Table 12: Glycemic indices of formulated ginger-based fruit drinks

Samples	Glycemic index
G50:P40:A10	48.39 ± 0.45^{b}
G50:P30:A20	42.47 ± 1.02^{c}
G50:P20:A30	38.49 ± 0.96^{d}
G50:P10:A40	34.28 ± 0.93^{e}
G100	21.58 ± 1.19^{f}
Comm	58.86 ± 1.12^{a}

Notes: Values with similar superscripts in the same column are not significantly different (p >0 .05).

G50:P40:A10—Ginger (50%): Pineapple (40%): Apple (10%). G50:P30:A20—Ginger (50%): Pineapple (30%): Apple (20%). G50:P20:A30—Ginger (50%): Pineapple (20%): Apple (30%). G50:P10:A40—Ginger (50%): Pineapple (10%): Apple (40%). G100—Ginger (100%). Comm, commercial ginger-based drink.

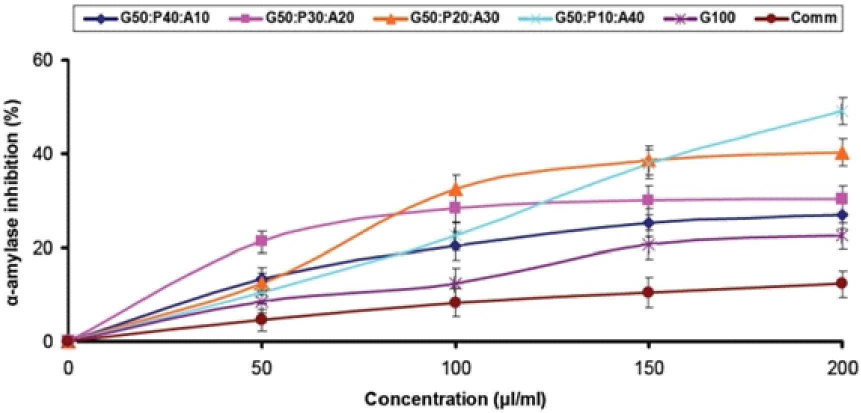


Figure 20: α-amylase inhibitory abilities of ginger-based fruit drinks. Values represent mean ± SD, number of samples n = 3. G50:P40:A10—Ginger (50%): Pineapple (40%): Apple (10%). G50:P30:A20—Ginger (50%): Pineapple (30%): Apple (20%). G50:P20:A30—Ginger (50%): Pineapple (20%): Apple (30%). G50:P10:A40—Ginger (50%): Pineapple (10%): Apple (40%). G100—Ginger (100%). Comm, commercial ginger-based drink.

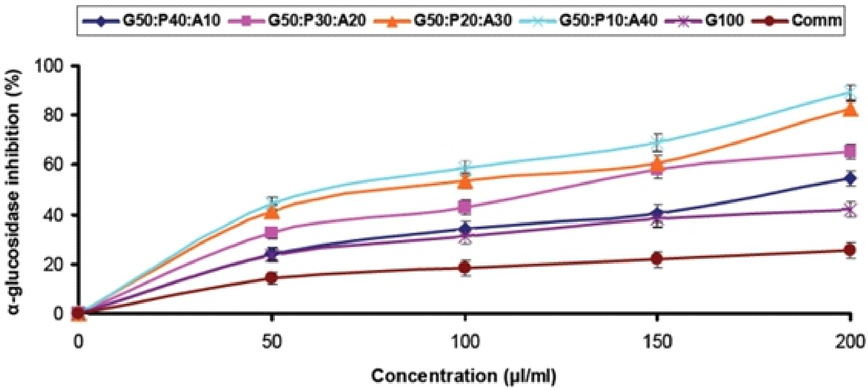


Figure 21: α-glucosidase inhibitory abilities of ginger-based fruit drinks. Values represent mean ± SD, number of samples n = 3. G50:P40:A10—Ginger (50%): Pineapple (40%): Apple (10%). G50:P30:A20—Ginger (50%): Pineapple (30%): Apple (20%). G50:P20:A30—Ginger (50%): Pineapple (20%): Apple (30%). G50:P10:A40—Ginger (50%): Pineapple (10%): Apple (40%). G100—Ginger (100%). Comm, commercial ginger-based drink

Mr. Vice Chancellor Sir, Omoba *et al.* (2021b) produced malted sorghum – ginger biscuit and investigated the chemical compositions, antioxidant activities and carbohydrate hydrolyzing enzymes activities of the sorghum – ginger biscuits. Total phenolic, (TPC), total flavonoid contents (TFC) were determined using standard methods, the ferric reducing antioxidant potential (FRAP), 2, 2-diphenyl-1-picryhydrazyl (DPPH) were used to assess the *in vitro* antioxidant properties of the biscuits. Biscuits phenolic compounds were identified and quantified using HPLC – DAD, while the carbohydrate hydrolyzing enzyme (α-amylase and α-glucosidase) activities of the biscuits were determined. High nutrient dense biscuits with medium to low glycemic indices (54 – 58) were produced, which suggest, the potential suitability of the biscuits for people managing type 2 DM.

3.4.1 Sweet potato (*Ipomoea batatas*) leaves

Sweet potato leaves are functional food capable of offering protection from degenerative diseases linked to oxidation such as cancer, allergies, aging, human immunodeficiency virus infection, and cardiovascular problems (Islam, 2006). Omoba *et al.* (2020) evaluated the chemical compositions, anti-nutrient compositions, antioxidant properties, and phenolic profile of the leaves of orange fleshed sweet potato varieties [King J (UMUSPO1) and Mother's Delight (UMUSPO2)] in Nigeria and their suitability in soup preparation. The study revelaed that the leaves of orange fleshed sweet potato varieties in Nigeria are good sources of nutritional antioxidants and could be suitable for the management of some disease conditions linked to oxidative stress.

3.5. Application of fruit processing wastes in healthy eating

Fruit processing wastes are valuable resource owing to the presence of a broad spectrum of bioactive moieties including polyphenols, antioxidants, proteins, dietary fibre, enzymes, flavouring aromas, organic acids, and minerals (Omoba, 2018). Utilization of fruit processing wastes in the production of high value-added products has increased the profitability of the fruit processing industry by reducing the cost of disposal of these wastes. In the past two decades, my research group had developed healthy foods from food processing waste such as brewers spent grain (BSG), Orange peels, tiger nut fibre, banana peel (Omoba *et al.,* 2013; Omoba *et al.,* 2015c; Omoba 2018; Oguntoyinbo *et al.,* 2020; Omoba *et al.,* 2021).

Omoba *et al.* (2013) developed high fibre biscuits from blends of plantain flour and Brewers' spent grains (BSG) with total dietary fibre ranging from 52.6 % to 68.6%. The proportion of soluble dietary fibre (SDF) and insoluble dietary fibre (IDF) in the biscuits were within the recommended values of 1:3 and 1:4; which are of nutritional significance. Insoluble fibre prevents constipation while soluble fibre reduces the cholesterol level in the blood, slows down digestion and sudden release of energy, thus stabilizing the blood glucose.

Omoba *et al.* (2015c) identified and quantified the phenolic compounds of unripe and ripe sweet orange peels using a high-performance liquid chromatography separation method with diode array. The predominant phenolic compounds were quercitrin, rutin, and quercetin with higher values in unripe orange peels compared to ripe orange peels. Ripe orange peels gave higher antioxidant properties (ABTS, FRAP, OH*) than the unripe orange peels. Incorporation of orange peels up to 10 % into pearl millet biscuits gave nutritionally improved products with significant health benefits (Obafaye & Omoba, 2018). Similarly, Omoba *et al.* (2021) developed fibre - riched cake using tigernut fibre (a residue from the production of tiger nut milk) and OFSP. The cake produced had higher total dietary fibre (9.88 - 10.68%), insoluble dietary fibre (7.76 - 8.41%).

The chemical composition, dietary fibre and antioxidant activity of fermented ripe banana peel flour derived from different varieties were investigated by Oguntoyinbo *et al.* (2020). Ripe fermented *Omini* banana (RFO) peel flour contained higher total phenolic content (34.03 GAE/g) and total flavonoid content (428 mg/100g), compared with other varieties. RFO peel had the highest polyphenols and carotenoids. It could therefore be incorporated into value-added foods of high dietary fibre content.

4.0. My contribution to decrease in food wastage through food processing system

Food wastes reduction interventions are specific activities and changes to the food system that lead to less food being lost or wasted across the supply chain. My research group had used different healthy methods to reduce food losses and wastages. Fasasi *et al.* (2002, 2003) investigated the effect of ^{60}Co irradiation on the chemical compositions, physical attributes (colour, texture) before and after storage of some fruits and leafy vegetables (Spinach (*Spinacia oleracea* L.) and Jew's mallow (*Corchorus olitorus L).* Results revealed that irradiation combined with low temperature was not effective for the postharvest storage of leafy vegetables, as the vitamin C, Ca and the fibre contents decreased ($p < 0.5$) and further decrease occurred with increasing days of storage.

Karim *et al.* (2011) assessed the impact of sulphiting pretreatment and packaging materials on some properties of stored dehydrated pineapple slices. The study concluded that sulphiting is a good pretreatment for conservation of quality for long-term storage of dried pineapple fruits, also laminated foil was ranked the best among the packaging materials used in preservation of quality.

Omoba and Onyekwere (2017) studied the postharvest properties of cucumber fruits (*Cucumber sativus L.)* treated with chitosan-lemon grass extracts at different storage durations. The combination of chitosan and lemon grass extract, especially 1.0% C +1.0% E as an edible coating, had great potential to preserve the physical characteristics of cucumber fruits at ambient temperature $28 \pm 2°C$ found in tropical countries.

Odewole et al., 2020a; 2020b, studied the effects of Pulsed Magnetic Fields (PMF) pre-treatment on the microstructures and elemental distribution of the sweet pepper and fluted pumpkin leaves. Results showed that the fresh and blanched samples of fluted pumpkin leaves gave microstructural features that were different from samples pretreated by magnetic field. Changes in microstructures of sweet pepper and fluted pumpkin leaves caused by magnetic field pretreatment consequently led to better retention/improvement in elemental distribution in contrast to blanched and fresh sweet pepper and fluted pumpkin.

5.0 CONCLUSIONS

Mr. Vice Chancellor Sir, distinguished guests, ladies and gentlemen, for about an hour, I have given an account of my stewardship as a researcher in the area of Food processing, products development and analysis; relating to the promotion of health and food security. This lecture has delved into ***Healthy Eating*** that are sustainable in the African context; applying plant based tropical crops in sustainable food systems. There is the need for dietary shift from junk foods to eating natural foods, particularly of plant origin, that would results in the availability of high fibres, vitamins and minerals, phytochemicals, and other nutrients needed to reduce the incidence of non-communicable diseases (NCDs) and to enhance the quality of life.

6.0 RECOMMENDATIONS

My researches have shown that unhealthy eating may show up in people as raised blood pressure, increased blood glucose level, elevated blood lipids and obesity. These are metabolic risk factors leading to NCDs and consequently premature death. I therefore make the following recommendations:

Public:

i. The general public need sensitization to shift from modern dietary pattern (junk diets), characterized by consumption of high calories, protein and animal-based foods, to the traditional (old) diets which are richer in bioactive compounds and fibres. This will reduce the enormous economic and healthcare costs resulting from the negative impact of junk foods.

ii. Eat a variety of fruits (two or more servings a day) and vegetables (three or more servings a day), especially dark green, red, and orange coloured vegetables. They are rich in antioxidants and polyphenols.

iii. Reduce daily intake of salt or sodium to less than 1,500 mg per day if older than 50 years of age; restrict or eliminate sodas and other sugar-added drinks that are high in calories and contain few or no nutrients. This reduces susceptibility to hypertension, diabetes or chronic kidney disease.

iv. Regular exercise is also essential in maintaining physical and mental health and well-being. These are effective in preventing excess weight gain or in maintaining weight loss. Healthier lifestyles are also associated with improved sleep and mood.

v. Regular medical checkup is important for early detection of potentially life-threatening health conditions or diseases.

University:

i. As diets are key elements of a healthy lifestyle, it is important that staff and students have access to healthy food on and off campus. This makes it easy to make healthy choices.

ii. University policy to improve students' diets should incorporate efforts to promote availability of low cost healthier food items such as brown rice,whole wheat bread, vegetables, fruits etc.on the campus.

iii. Over indulgence in alcohol consumption and tobacco smoking can also have a negative impact on both mental and physical well- being of staff and students; ensuring that staff and students have access to non-alcoholic social activities on campus sends a clear message that drinking large volume of alcohol is not a necessary component of the higher education experience.

iv. Regular medical checkup should be encouraged for both staff and students.

Government:

i. Governments have a role to play in improving access to and consumption of healthy, safe and affordable foods. This can be achieved by formulating policies to enhance improved labelling on foods and drinks. This will assist consumers to make healthy choices.

ii. Government can serve as catalyst for community change by offering healthier foods (fruits, vegetables and whole grain products) at government facilities; using zoning laws to change local food environments (*i.e.,* opening of farmers' market).

iii. Raise awareness about the importance of healthy eating, through print and electronic media and health educators, educating people on consumption of healthy diets and physical activities.

iv. Make essential gym equipment available and accessible at local levels to encourage the populace in exercising or physical activities.

v. Provision of more fund for research, to enable researchers generate data on the available but underutilized tropical crops sustainable in our agricultural system; that can produce healthy diets to achieve dietary shift.

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REFERENCES

Ademosun, M.T., **Omoba, O.S.** & Olagunju, A.I. (2021). Antioxidant properties, glycemic indices, and carbohydrate hydrolyzing enzymes activities of formulated ginger-based fruit drinks. *Journal* of *Food Biochemistry 45(3)*:e13324.

Adeyemi, I.A. & Beckley, O. (1986). Effect of period of maize fermentation and souring on chemical properties and amylograph pasting viscosity of *Ogi*. *Cereal Science* 4: 353-360.

Akinyede, A.I., Girgih, A.T., Osundahunsi, O.F., Fagbemi, T.N. & Aluko, R.E. (2017). Effect of membrane processing on amino acid composition and antioxidant properties of marble vine seed (*Dioclea reflexa*) protein hydrolysate. *Journal of Food Processing and Preservation*. 41:e12917.

Ajatta, M.A., Akinola, S.A., Otolowo, D.T., Awolu O.O., **Omoba, O.S.** & Osundahunsi, O.F. (2019). Effect of Roasting on the Phytochemical Properties of Three Varieties of Marble Vine (*Dioclea reflexa*) Using Response Surface Methodology. *Preventive Nutrition and Food Science*, 24(4):468-477.

Ajatta, M. A., Oladipupo, O. R., Josiah, S. S., Osundahunsi, O. F. & **Omoba, O. S.** (2020). Cognitive impairment by non-insulin-dependent diabetes mellitus was attenuated by dietary supplements of marble vine (*Dioclea reflexa*) and plantain (*Musa paradisiaca*) dough meals in albino rats *Journal* of *Food Biochemistry 45(3)*:e13473.

Ajatta, M.A., Akinola, S.A., Osundahunsi, O.F. & **Omoba, O.S.** (2021). Effect of roasting on the chemical composition, functional characterisation and antioxidant activities of three varieties of marble vine (*Dioclea reflexa*): An underutilised plant. Heliyon 7: e07107: https://doi.org/10.1016/j.heliyon.2021.e07107.

Anya, M.I. & Ozung, P.O. (2019). Proximate, mineral and anti-nutritional compositions of raw and processed African Yambean (*Sphenostylis stenocarpa*) seeds in Cross River State, Nigeria. *Global Journal of Agricultural* Sciences *18(1) : 19*.

Awolu, O.O., **Omoba, O.S.,** Olawoye, O. & Dairo, M. (2016). Optimization of production and quality evaluation of maize –

based snack supplemented with soybean and tigernut *(Cyperus esculenta*) flour. *Food Science and Nutrition* 5 (1) 3 -13.

Bayata, A. (2019). Review on Nutritional Value of Cassava for Use as a Staple Food. *Science Journal of Analytical Chemistry.* 7 (4) : 83-91.

Beaton, G. H. & Swiss, L. D.(1974). Evaluation of the nutritional quality of food supplies: prediction of "desirable" or "safe" protein:calorie ratios, *The American Journal of Clinical Nutrition*, 27 (5) : 485–504.

Choi, Y., Jeong, H.S. & Lee, J. (2007). Antioxidant activity of methanolic extracts from some some grains consumed in Korea. *Food Chemistry* 103 (1): 130-138.

Erdman, J. W Jr., Balentine, D., Arab, L., Beecher, G., Dwyer, J. T., Folts, J., Harnly, J., Hollman, P., Keen, C. L., Mazza, G., Messina, M., Scalbert, A., Vita, J., Williamson, G. & Burrowes J. (2007). Flavonoids and heart health: Proceedings of the ILSI North America Flavonoids Workshop, May 31-June 1, 2005, Washington, DC. J Nutr 137:718S–37S.

Esan, O.Y. & **Fasasi, O.S.** (2013). Amino acid composition and antioxidant properties of African Yam Bean (*Spenostylis stenocarp*) protein hydrolysates. *African Journal of Food Science and Technology* 4(5): 100 – 105.

Esan, Y.O., **Omoba, O.S.** & Enujiugha, V.N. (2018a). Biochemical and nutritional compositions of two accessions of *Amaranthus Cruentus* seed flour. *American Journal of Food Science and Technology,* 6 (4): 145-150.

Esan, Y.O., **Omoba, O.S.**, Enujiugha, V.N. & Okoh, O.O. (2018b). Functional and antioxidant properties of raw and popped Ama- ranth (*Amaranthus cruentus*) seeds flour. *Annals. Food Science and Technology*, 19(2): 399–408.

Esan, Y.O., **Omoba, O.S.**, Enujiugha, V.N. & Okoh, O.O. (2019). Amino acid composition of amaranth seed flour and protein hydrolysates. Paper presented at the Pharm – Food Congress, Federal University of Technology, Akure.

Eyzaguirre, R.Z., Nienaltowska, K., de Jong, L.E.Q., Hasenack, B.B.E. & Nout, M.J.R. (2006). Effect of food processing of pearl millet (*Pennisetum glaucum*) IKMP-5 on the level of phenolics, phytate, iron and zinc. *J Sci Food Agric* 86:1391–1398.

Fagbenro, O.A., **Fasasi, O.S.**, Jegede, T. & Olawusi – Peters, O. O. (2011). 60 years of tilapia aquaculture in Nigeria. Pp.300 – 309, In: Proceedings of the Ninth International Symposium on Tilapia in Aquaculture (ISTA 9), (Liping, L. & Fitzsimmons, K., eds.), Shanghai, China.

Fagbenro, O.A.(2002) Tilapia: fish for thought. 32nd Inaugural Lecture, Federal University of Technology, Akure, Nigeria. 77pp.

Faisel, H. & Pittrof, R. (2000). Vitamin A and causes of maternal mortality: association and biological plausibility. *Public Health Nutr*ition 3:321–327

Fasasi, O.S., Aborisade, A.T. & Adetuyi, F.C. (2002). Combined effect of ^{60}Co irradiation on the storage life of Spinach (*Spinacia oleracea*) and Jew's mallow (*Corchorus olitorus*). *Applied Tropical Agriculture* 7(1&2) : 12 - 18.

Fasasi O.S., Eleyinmi, A.F. & Fasasi, A.R. (2003). Effect of ^{60}Co irradiation on the storage life of bell pepper (*Capsicum annum L.*) and tomatoes (*Lycopersicon esculentum Mill*) stored at low temperature. *Ghana Journal of Chemistry* 5 (2): 93 – 113.

Fasasi, O.S., Adeyemi, I.A. & Fagbenro, O.A. (2005). Proximate composition and multi enzyme in vitro protein digestibility of maize – tilapia flour blend. *Journal Food Technology* 3: 342 – 345.

Fasasi, O.S., Adeyemi, I.A. & Fagbenro, O.A. (2006). Physicochemical properties of maize-tilapia flour blends. Proceedings of the Seventh International Symposium on Tilapia in Aquaculture (W.M. Contreras-Sanchez and K. Fitzsimmons, eds.). Veracruz, Mexico.

Fasasi, O.S., Adeyemi, I.A. & Fagbenro, O.A. (2007). Functional and pasting characteristics of fermented maize and Nile Tilapia (*Oreochromis niloticus*) flour diet. *Pakistan Journal of Nutrition* 6 (4): 304 – 309.

Fasasi, O.S. (2009a). Effect of processing methods on the proximate and functional properties of quality protein maize (QPM) seed flour. *Applied Tropical Agriculture* 14 (1&2): 43 – 48.

Fasasi, O.S. (2009b). Proximate, antinutritional factors and functional properties of pearl millet (*Pennisetum glaucum*). *Journal of Food Technology* 7: 92 – 97.

Fasasi, O.S., Oyebode E.T. & Olusanya D. (2009). Proximate and functional properties of modified Bambara isolate - "*ogi*" mix as complimentary diet. *Acta Horticulturae* 806 (1): 301 – 306.

Fasasi, O.S., Adeyemi, I.A. & Fagbenro O.A. (2010). Proximate, minerals, amino acid and fatty acid composition of fermented cassava flour '*fufu'* – Fish Powder mix. *Nigeria Food Journal* 28 (2): 81 – 90.

Fasasi, O.S. & Karim, O.R. (2011). Chemical composition, Resistant, Total Starch content and acceptability of Noodle substituted with cowpea starch. *Nigeria Food Journal* 29(1): 6 – 11.

Fasasi, O.S., Oyebode, E.T. & Fagbamila, O. (2012). Effect of enzyme/substrate ratio on the antioxidant properties of hydrolysed African yam bean. *African Journal of Biotechnology* 11(50):11086 - 11091.

Fasasi O. S. (2012). Heamatological studies and performance of rat fed with wheat – pigeon pea flour blend. In Research and Capacity building for Agricultural transformation in Nigeria. (Adebayo, A.I., Adekunle, V. A. J., Oseni, J. O. & Awodun, M. A. – editors). Proceedings of 6th Annual Conf., Schl. of Agric & Agric Tech., Federal University of Technology, Akure, Nigeria. 21st May, 2012, 120 – 127.

Fasasi, O. S. & Alokun, A.O.(2013) Physicochemical properties, vitamins, antioxidant activities and amino acid composition of ginger spiced maize snack 'kokoro' enriched with soy flour (a Nigeria based snack). *Agricultural Sciences*, 4: 73-77.

Gänzle, M.G. (2014). Enzymatic and bacterial conversions during sourdough fermentation. *Food Microbiology,* 37 : 2-10.

Guo, H., Kouzuma, Y. & Yonekura, M. (2009). Structures and properties of antioxidative peptides derived from royal jelly protein. *Food Chemistry* 113: 238-245.

Halliwell B. (1987). Oxidants and human-disease: some new concepts. FASEB J 1:358–64.

Harvard T.H. Chan School of Public Health (2005): www.thenutritionsource.org*, and Eat, Drink, and Be Healthy,* *by Walter C. Willett, M.D., and Patrick J. Skerrett, Free Press/Simon & Schuster Inc."*

Ifesan, B.O.T., **Fasasi, O.S.** & Osundahunsi, O.F. (2011). Physicochemical and Antioxidant Properties of Turmeric (*Curcuma Longa*) and Ginger (*Zingiber officinale*). *Applied Tropical Agriculture* 15(1&2): 60 – 64.

Ifesan, B.O.T., **Fasasi, O.S.** & Ehioniyotan, F.A. (2012). Production of bread - spread from blends of Shea butter (*Vitellaria paradoxa*), Garlic (*Allium sativum*), Ginger (*Zingiber officinale*), Scent leaf (*Occimum gratissimum*) and *Suya* Spice. *Journal of Microbiology, Biotechnology and Food Science* 1 (6): 1406 – 1423.

Islam, S. (2006). Sweet potato (*Ipomoea batatas* L.) leaf: its potential effect on human health and nutrition. *J Food Sci. 71:R13-R121.*

Izge, A.U., & Song, I.M. (2013). Pearl millet breeding and production in Nigeria: problems and prospects. *Journal of Environmental Issues and Agriculture in Developing Countries,* 5(2), 25.

Karim, O.R., **Fasasi O.S.** & Adebowale, A.A. (2011). Impact of sulphiting pretreatment and packaging materials on some properties of stored dehydrated pineapple slices. *Journal of Applied and Environmental Sciences* 6(3): 94 – 100.

Lean Michael E.J. (2015). "Principles of Human Nutrition". *Medicine*. 43 (2): 61– 65. doi:10.1016/j.mpmed.2014.11.009.

Makanjuola, S. A., Enujiugha, V. N., **Omoba, O.S.,** & Sanni, D. M. (2015a). Application of RSM and Multivariate Statistics in Predicting Antioxidant Property of Ethanolic Extracts of Tea-Ginger Blend. *European Journal of Medicinal Plants* 6(4): 200-211.

Makanjuola, S.A., Enujiugha, V.N., **Omoba, O.S.,** & Sanni, D.M. (2015b). Optimization and prediction of antioxidant properties of a tea-ginger extract. *Food Science and Nutrition,* 3(5): 443 – 452.

Makanjuola, S.A., Enujiugha, V.N., **Omoba, O.S.,** & Sanni, D.M. (2015c). Combination of antioxidants from different sources could offer synergistic benefits: A case study of tea and ginger blend. *Natural Product Communications,* 10 (11): 1829 –

1832.
Makanjuola, S.A., Enujiugha, V.N. & **Omoba, O.S.** (2016). Multiresponse Optimization and prediction of antioxidant properties of aqueous ginger extract. *Preventive Nutrition and Food Science,* 21 (4): 355 – 360.
Makanjuola, S.A., Enujiugha, V.N., **Omoba, O.S.,** & Sanni, D.M. (2020). Modelling and Prediction of Antioxidant Properties of Tea (*Camellia sinensis* (L.) Kuntze) Leaf. Scientific African, doi:https://doi.org/10.1016/j.sciaf.2020.e00455.
Montagnac, J. A., Davis, C. R. &Tanumihardjo, S. A. (2009) "Nutritional value of cassava for use as staple food and recent advances for improvement," *Composite Review in Food Science and Food Safety*, 8 (3): 181 -194.
Motsa, N. M., Modi, A. T. & Mabhaudhi, T. (2015) Sweet Potato (*Ipomoea Batatas L.*) as a Drought Tolerant and Food Security Crop. *South African Journal of Science.* 111(11/12):1-8.
National Research Council (1989) *Recommended Dietary Allowances*, National Academy Press, Washington, DC, USA.
Obafaye, R.O. & **Omoba O.S.** (2018). Orange peel flour: A potential source of antioxidant and dietary fiber in pearl-millet biscuit. *Journal of Food Biochemistry*. 42, e12523.
Odewole, M.M., Olalusi, A.P., Oyerinde, A.S. & **Omoba, O.S.** (2020a). Microstructures and elemental distribution of magnetic field pre – treated fluted pumpkin leaf. *Acta Technologica Agriculturae* 1: 12 – 17.
Odewole, M.M., Olalusi, A.P., **Omoba, O.S.** & Oyerinde, A.S. (2020b). Microstructural characteristics and elemental distribution of magnetic field pretreated sweet pepper. *Carpathian Journal of Food Science and Technology* https://doi.org/10.34302/crpjfst/2020.12.3.4
Ogbonna, A.C. (2011). Current developments in malting and brewing trials with sorghum in Nigeria: A Review. *Journal of Institute of Brewing* 117, 394-400
Ogunnowo, O.C., **Omoba, O.S.** & Olagunju, A.I. (2021). Functional properties, *in vitro* starch hydrolysis index and predicted glycemic index of processed cream and orange fleshed sweet potato. *Journal of Food Processing and*

Preservation (Submitted)

Oguntoyinbo, O.O., Olumurewa, J.A.V. & **Omoba, O. S.** (2020). Chemical Composition, Dietary fibre and Antioxidant Activity of Fermented Ripe Banana Peel Flour. *Journal of Food Stability*, 3 (2), 27-42

Olagunju, A.I., **Omoba, O.S.,** Enujiugha,V.N. & Alashi, A.M (2018a). Antioxidant properties, ACE/renin inhibitory activities of pigeon pea hydrolysates and effects on systolic blood pressure of spontaneously hypertensive rats. *Food Science & Nutrition*, *6(7):* 1879–1889.

Olagunju, A.I., **Omoba, O. S.,** Enujiugha,V.N., Aluko, R.E. &Alashi, A.M. (2018b). Pigeon pea enzymatic protein hydrolysates and ultrafiltration peptide fractions as potential sources of antioxidant peptides: An *in vitro* study *LWT* 97: 269-278.

Olagunju, A.I., **Omoba, O.S.,** Enujiugha,V.N. & Aluko, R.E. (2018c). Development of value-added nutritious crackers with high antidiabetic properties from blends of Acha (*Digitaria exilis*) and blanched pigeon pea (*Cajanus cajan*). *Food Science & Nutrition* 6(7): 1791-1802.

Olagunju, A.I., **Omoba, O.S.,** Enujiugha, V.N., Alashi, A.M. & Aluko, R.E. (2020a). Thermoase-hydrolysed pigeon pea protein and its membrane fractions possess *in vitro* bioactive properties (antioxidative, antihypertensive, and antidiabetic). *J Food Biochem*.; 00:e13429. https://doi.org/10.1111/jfbc.13429

Olagunju, A.I., **Omoba, O.S.,** Enujiugha, V.N., Weins, R.A., Gough, K.M. & Aluko, R. (2020b). Influence of acetylation on physicochemical and morphological characteristics of pigeon pea starch. *Food Hydrocolloids* 100: 105424

Olagunju, A.I., **Omoba, O.S.,** Enujiugha, V.N., Aluko, R.E. & Alashi, A.M. (2020c). Technological Properties of Acetylated Pigeon Pea Starch and Its Stabilized Set-Type Yoghurt. *Foods* · DOI: 10.3390/foods9070957.

Olagunju, A.I., **Omoba, O.S.,** Awolu, O.O., Rotowa, K.O., Oloniyo, R.O. & Ogunnowo O.C. (2020d). Physiochemical, Antioxidant Properties and Carotenoid Retention/Loss of Culinary Processed Orange Fleshed Sweet Potato. *Journal of*

Culinary Science & Technology https://doi.org/10.1080/15428052.2020.1799278.

Oloniyo, R.O., **Omoba, O.S.,** Awolu, O.O. & Olagunju, A.I. (2020). Orange-fleshed sweet potatoes composite bread: A good carrier of beta (β)-carotene and antioxidant properties. *J Food Biochem*. 2020;00: e13423.

Oloniyo, R.O., **Omoba, O.S.** & Awolu, O.O. (2021). Biochemical and antioxidant properties of cream and orange-fleshed sweet potato. *Heliyon* 7: e06533

Omoba, O.S. & Omogbemile, A. (2013). Physicochemical properties of sorghum biscuit enriched with defatted soy flour. *British Journal of Applied Science & Technology 3*(4): 1246 – 1256.

Omoba, O.S., Awolu, O.O., Olagunju, A.I. & Akomolafe, A. O. (2013). Optimization of plantain –brewers' spent grain biscuit using Response Surface Methodology. *Journal of Scientific Research and Report* 2 (2) 665-681.

Omoba, O.S., Dada, A.O. & Salawu, S.O. (2015a). Antioxidant properties and consumer acceptability of pearl millet - tiger nut biscuits. *Nutrition and Food Science* 6 (45): .818 – 828

Omoba, O.S., De Kock, H.L. & Taylor, J.R.N. (2015b). Sensory and nutritive profiles of biscuits from whole grain sorghum and pearl millet plus soy flour with and without sourdough fermentation. *International Journal of Food Science & Technology,* 50 (12):2554 – 2561.

Omoba, O.S., Obafaye, R.O., Salawu, S.O., Boligon, A.A., & Athayde, M.L. (2015c). HPLC-DAD phenolic characterization and antioxidant activities of ripe and unripe sweet orange peels. *Antioxidants,* 4: 498-512

Omoba, O.S. & Azeez, H.I. (2016). Quality characteristics and overall acceptability of steamed and boiled blue whiting fish (*Micromesistius poutassou*) cracker", Nutrition & Food Science, 46 (6): 857 – 870.

Omoba, O.S. & Onyekwere, U. (2017). Postharvest properties of cucumber fruits (*Cucumber sativus L.)* treated with chitosan-lemon grass extracts under different storage durations. *African Journal of Biotechnology*, 15(50): 2758-2766.

Omoba, O.S. & Isah, L.R. (2018**).** Influence of sourdough fermentation on amino acid compositions, phenolic profile, and antioxidant properties of sorghum biscuits. *Preventive Nutrition and Food Science.* 23(3):220-227.

Omoba, O.S. (2018). The potential nutritional benefits of agricultural wastes and by – products in an insurgence – ravaged economy. A review. In O. F. Osundahunsi (Ed) Roadmap to improve livelihoods in Africa. .the book: Pg. 264 – 276, Simplicity press, Nigeria.

Omoba, **O. S.**, Olagunju,A.I., Salawu, S.O. & Boligon, A. A. (2019). HPLC-DAD phenolic profiling and *in vitro* antioxidant activities of three prominent Nigerian spices. *Preventive Nutrition and Food Science.* 24(2):179 -186.

Omoba, O.S., Oyewole, G.O. & Oloniyo, R.O. (2020). Chemical compositions and antioxidant properties of orange fleshed sweet potato leaves and the consumer acceptability in vegetable soup. *Preventive Nutrition and Food Science* 25(3):293- 300.

Omoba, O.S., Olagunju, A.I., Iwaeni, O.O. & Obafaye, R.O. (2021a). Effects of tiger nut fiber on the quality characteristics and consumer acceptability of cakes made from orange-fleshed sweet potato flour. *Journal of Culinary Science & Technology*, 19 (3) 228 -246.

Omoba, O.S., Olagunju, A.I., Akinrinlola, F.O. & Oluwajuyitan, T.D. (2021b). Shallot – Enriched Extruded Snack Ameliorate Oxidative Stress in STZ – Induced Diabetic Rat Model. *British Journal of Nutrition.* (Submitted).

Omoba, O.S., Ademosun, M.T., Akinrinlola, F.O., Sonde, D.T., Boligon, A. A. (2021c). Chemical compositions, antioxidant activities and carbohydrate hydrolyzing enzymes activities of sorghum – ginger biscuits. *Journal of Food Measurement and Characterization (submitted)*

Rahman, M., Patwary, M., Barua, H., Hussain, M., & Nahar, S. (2013). Evaluation of orange fleshed sweet potato (*Ipomea batatas* L.) genotypes for higher yield and quality. *Agriculturists,* 11(2), 21–27.

Tinus, T., Damour, M., Van Riel, V. & Sopade, P.A. (2012). Particle sizestarch–protein digestibility relationships in cowpea (*Vigna unguiculata*). *Journal* of *Food Engineering,* 113:254–264.

Tokusoglu, O., & Yildirim, Z. (2012). Effects of cooking methods on the anthocyanin levels and antioxidant activity of a local Turkish sweet potato [*Ipeomoea batatas* (L.) Lam] cultivar Hatay kirmizi: Boiling, steaming and frying effects. *Turkish Journal of Field Crops*, 7: 87–90.

United Nations World Population Division (2017). http://www.un.org/ en/development/desa/population/. Accessed 20 Dec 2017.

Vasal, SK, (2000). The quality protein maize story. *Food and Nutrition Bulletin*, The United Nations University; 21:4.

Venskutonis, P.R. & Kraujalis, P. (2013). Nutritional components of amaranth seeds and vegetables: a review on composition, properties, and uses. *Comprehensive Review in Food Science and Food Safety* 12(4):381–412.

WHO/FAO/UNU (2007). Protein and Amino Acid Requirements in Human Nutrition; Report of a joint WHO/FAO/UNU Expert Consultation, WHO Tech Rep Ser no. 935. Geneva: WHO.

World Health Organization (2013). Global action plan for the prevention and control of noncommunicable diseases: 2013–2020. Geneva: WHO; Available at: https://www.who.int/nmh/events/ncd_action_plan/en/.