PRODUCTION AND EVALUATION OF DIETARY FIBER FROM CITRUS WASTE FOR FORTIFICATION OF "JUNK" FOODS

BY

ATOYEBI AYOMIDE ELIZABETH

MATRIC. NO.: 17010501002

DEPARTMENT OF FOOD SCIENCE AND TECHNOLOGY

MOUNTAIN TOP UNIVERSITY

PRAYER CITY, IBAFO, OGUN STATE.

IN PARTIAL FULFILMENT OF REQUIREMENT FOR THE AWARD OF BACHELOR OF SCIENCE (B.Sc.) IN FOOD SCIENCE AND TECHNOLOGY.

DECLARATION

I hereby declare this is an original work done by me and is a record of my own research work. It has not been presented in any previous application of any higher degree of this or any other University. All citation and sources of information are clearly acknowledged by means of reference.

……..

ATOYEBI AYOMIDE ELIZABETH

……..

Date

CERTIFICATION

This is to certify that the content of this project entitled **'Production and Evaluation of Dietary fiber from Citrus waste for Fortification of "Junk" Foods** was prepared and submitted by ATOYEBI AYOMIDE ELIZABETH in partial requirements for the degree of BACHELOR OF SCIENCE IN FOOD SCIENCE AND TECHNOLOGY. The original research work was carried out by under my supervision and is hereby accepted.

…… (Signature and Date)

Dr. D.T. Otowolo

Supervisor

…….. (Signature and Date)

Dr.(Mrs.) M. O. Omosebi

Head of Department

DEDICATION

I dedicate this research work to God Almighty for His love, guidance, provision, throughout my years of study. Also my parents for always being there to support and encourage me throughout my academic years

ACKNOWLEDGEMENT

My heartfelt thanks go to Almighty God, who has protected and provided the resources required for this research work through his unfailing life and grace.

I would like to express my heartfelt appreciation to my supervisor, Dr. D. T. Otowolo, for her time, suggestions, and guidance during the supervision and correction of this work.

Also, I like to thank my HOD, Dr. (Mrs.) M. O. Omosebi, as well as my lecturers, Dr. A.O Idowu, Dr. O. A. Babarinsa, Dr. S.S. Sobowale, Mr. G. D. Ayandiran, Mrs. M. D. Amidu, and Miss. Ranti.

My heartfelt gratitude goes to my parents, Mr. and Mrs. Atoyebi, as well as my siblings Adeola, Oyebola, and Oyeyemi, for their love, financial and moral support, and prayers throughout the ordeal.

Also, a huge thank you to Glory. Damilola and Modupe for their help and for being the best course mates and my friends Feranmi, Toluwalase, Oluwafemi, Ayomide, Tosin, Comfort, Japheth and Fred for their assistance.

TABLE OF CONTENTS

CHAPTER TWO

LIST OF TABLES

LIST OF APPENDIX

ABSTRACT

Citrus fruits are one of the commercially grown fruits and are high in phytochemicals and biologically active substances that have health benefits. However, the processing of citrus fruits generates approximately 50% waste (in the form of peel, pulp, seeds, pith, and so on), which is generally discarded into the environment, causing pollution. Coronary heart disease, diabetes, and stroke are all common in today's world as a result of habitual consumption of "junk" foods. Citrus waste dietary fiber added to "junk" foods may aid in disease prevention.

The fortified “Junk” foods with percentage citrus waste fiber inclusion are; cake and doughnut (15% as wheat flour and fat replacer); ice-cream (2% as adjunct); and sausage (10% as wheat flour and fat replacer). The products were evaluated for proximate composition, Lab colour, microbial load, and sensory acceptability having the unfortified products as the control in each of the product. The citrus waste dietary fiber powder produced exhibited good antioxidant and functional properties. The fortified ‘junk’ foods had moisture contents (20.66, 19.62, 60.83, and 54.00%) for cake, doughnut, ice-cream, and sausage, respectively that were lower than those of the respective control samples (23.47, 20.93, 63.99, and 57.50). On the other hand, it was discovered that the crude fiber contents (0.66, 1.04, 1.14 and 0.68%) were higher than those of the corresponding control samples (0.08, 0.29, 0.32 and 0.61%). This could be as a result of increased total solid content due to the addition of citrus waste dietary fiber powder which may improve the shelf life of the fortified products and the increased fiber contents showed the improvement of the nutritional value and consequent health benefits of the fortified products. The products were well acceptable by the panelists’ ratings and the lab colour evaluation showed no significant ($p<0.05$) difference with the control samples while total viable bacteria and total viable fungi load (ranges of 7.0×10^1 to 1.2×10^4 CFU/ml and 2.0×10^1 to 2.0×10^3 CFU/ml, respectively) were within the standard acceptable level for a safe food product.

In conclusion, the application of citrus waste dietary fiber in fortifying “junk” foods proved effective in improving the nutritional value, particularly dietary fiber content, indicating the potential for additional health benefits.

Keywords: Citrus wastes, “junk” foods, dietary fiber fortification, nutritional and sensory properties, microbial loads

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

Citrus is a generic term for plants in the Rutaceae family. It is a popular fruit all over the world, with one-third of the crop processed (Tomar et al., 2013). This family has abundant phytochemical sources for numerous bioactive compounds that are in charge of many biological processes, including the production of antioxidants. Vitamin C and other vitamins and minerals make up the majority of the nutrients in citrus fruits (Carr and Vissers, 2013).

Citrus fruits are widely consumed throughout the world as fresh produce, juice, and, in some cases, candied products, resulting in the production of approximately 50% waste (including fiber-rich peels, seeds, and membrane residues) (Sharma et al., 2017). These leftovers, which are typically discarded and viewed as environmental waste, could be a source for nutraceuticals.

Due to their low cost and ease of access, such wastes can provide significant low-cost dietary nutritional supplements. Furthermore, due to the volume produced, citrus byproduct processing may be a significant source of phenolic compounds and dietary fiber (Raffiq et al., 2018).

"Junk" foods are assumed to be inexpensive, convenient, easily accessible, and tasty, despite having little nutrients and a high fat content calorie index (Adamo and Brett, 2014). Consumption of which may result in dietary disorders such as dietary deficiencies or excesses, obesity and eating disorders, as well as chronic diseases such as cardiovascular disease, hypertension, cancer, likewise type 2 diabetes if consistently carried out (Gupta et al., 2017).

Fiber is a carbohydrate that is not digestible and lignin that has been connected to a number of health benefits. Dietary fibers are those found in plants (Elleuch et al., 2011). Dietary fibers, particularly soluble fiber, are essential components of any heart-healthy diet because they can improve health. Low-density lipoprotein (LDL), also known as bad cholesterol, can be decreased through a high-fiber diet, which can also reduce the risk of metabolic disorder; a risk factor associated with diabetes coronary heart disease, and stroke (Dinu et al., 2017).

1.2 Statement of the Problem

Due to its low cost and versatility in satiating appetite, junk foods have been among the most popular foods by humans. However, due to clinical studies demonstrating that some constituents of junk foods are associated with deleterious health consequences like obesity, diabetes, heart diseases, and high blood pressure, its consumption has raised concerns among the health-conscious and risk-prone population.

Also, poor waste management resulted in citrus waste being dumped on the land, ponded, or flushed into streams, lakes, or sewers, which was unsatisfactory and dangerous. A pile of rotting citrus fruits soon begins to sink; underground water supplies are contaminated, the increased biochemical oxygen demand kills aquatic life, and great degradation of the quality of soil and environmental pollution.

1.3 Justification of the Research

Even though the rate of change in consumption habit is slow, fortifying "junk" foods with citrus wastes dietary fibre could solve the problem of human health effects and as well reduce the environmental pollution effect of poor management of the wastes. Thereby, establishing a useful application for citrus wastes in food system.

1.4 Aim and Objectives of the Study

The major aim of this research is to improve the nutritive value of "junk" food through the fortification with citrus waste dietary fibre.

The specific objectives are:

- extraction of dietary fiber from citrus wastes and evaluation of the soluble and insoluble dietary fibre ratio, functional properties, phytochemical constituents, and antioxidant potential of the citrus waste fibre,
- production of citrus fiber fortified "junk" foods (cake, doughnut, ice cream and beef sausage),
- determination of the proximate composition of the fortified junk food products, and

- assessment of Lab colour, microbial load and consumer acceptability of the fortified “junk” food products.

1.5 Scope of the Study

This body of work focused on the production of citrus fiber from citrus waste derived from citrus fruits such as Orange *(Citrus X sinensis),* white and red Grapefruit *(Citrus X paradisi),* and lemon *(Citrus limon).* The nutritional value and acceptance of the citrus waste dietary fiber fortified junk foods by consumers was evaluated.

1.6 Significance of Study

Based on previous studies 37% of adults in America's population consumes “junk” food, and a portion of this population is addicted to it, which causes a high rate of defects on human health, including obesity, diabetes, heart diseases, and high blood pressure. Moreover, more than 33% of adults and 17% of children and teenagers are obese in United States (Dumanovsky et al., 2011). In Nigeria, over 75% of university students (42.9% males and 32.9% females) patronise and consume “junk” foods (Afolabi et al., 2013). The alternative remedy is fortifying “junk food” with dietary fiber which may not stop addicted consumers from eating but will support their health by improving digestion and helping to prevent heart-related diseases.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Citrus fruits

Citrus L. is a genus in the Rutaceae family and the Aurantioideae subfamily (Nagano et al., 2018). One of the most widely used common products in the world, with over 100 countries growing them. Because of their soil and favorable climatic conditions, subtropical and tropical areas are ideal for growing these types of fruits. Orange (61%), lime and lemon (11%), mandarin (22%), and grapefruit (6%), are the most essential citrus fruits. Commercially, these fruits are important in both the fresh-consumption market and the processing industry. According to estimates, 33% of the citrus crop is consumed by the citrus-processing industry, which has long specialized in fruit juice production harvest. In addition, most, if not all, are recycled. For example, while approximately 70% of manufactured oranges are used to make derivative products, nearly 50%-60% of them are wasted (peels, seeds, and membrane residue) (Taghizadeh-Alisaraei et al., 2017)

Lemons, grapefruits, limes, oranges, tangerines, and mandarins are the most cultivated fruits in the world, with production increasing year after year as consumer demand rises. The majority of these fruits, however, are wasted during industrial processing; for example, citrus peel waste accounts for roughly a half of the wet mass. These substantial citrus waste amounts contain high levels of flavonoids, dietary fiber, polyphenols, carotenoids, essential oils, sugars, ascorbic acid, and trace elements.

Sweet orange (*Citrus sinensis*) is the most abundant and widely consumed citrus fruit, accounting for 70% of total production and consumption. Other popular citrus fruits include lemon (*Citrus limonum*), grapefruit (*Citrus vitis*) lime (*Citrus aurantifolia*).and tangerine or mandarin (*Citrus reticulate*), Citrus fruit and its derivatives are well known for having high levels of vitamins, minerals, and dietary fibers, all of which are essential for human nutrition, growth, and development. (Mahato et al., 2018). Citrus fruits are also well-known for their active compounds, such as flavonoids, vitamins, carotenoids, and minerals, which may help to lessen the danger of a number of chronic diseases (e.g., cardiovascular diseases and age-related macular degeneration.). These bioactive ingredients have anti-cancer, anti-tumor, and antioxidant properties. These compounds have antimicrobial, anticancer, antiplatelet aggregation, and anti-inflammatory

properties. As was previously mentioned, subtropical and tropical regions produce the majority of citrus fruits, with a yearly production of about 88 million tons (Mahato et al., 2018)

Due to the rising demand for low-fat carbohydrates, low-sodium minerals, dietary fibers, and vitamins (particularly B complex and C), citrus fruits have become an essential component of the human diet. Approximately 80% of citrus fruits are used in the production of juice, marmalades, jams, jellies, and other similar processed products, resulting in approximately 40 million tons of waste. (Sharma et al., 2017).

Citrus fruits differ in terms of type, variety, quality, and degree of maturity. Citrus wastes contain soluble sugar, starch, cellulose and hemicellulose fibers, ash, pectin, lignin, fat, and protein, as well as some bioactive compounds that could be used in a range of applications ranging from pharmaceutical and nutraceutical to food, healthy drinks, and cosmetics. These are materials that are renewable and have economic value. As a result, the cost of the formulated product is reduced, and using these wastes can help the environment from pollution. Furthermore, these natural bioactive compounds, which are thought to significantly protect people from a variety of diseases, are used effectively in therapeutic formulation (Mahato et al., 2018).

2.2 Oranges

Orange refers to the fruit of various citrus species in the Rutaceae family, Citrus sinensis, also known as sweet orange, to differentiate it from the related Citrus aurantium, known as bitter orange. Sweet oranges have asexual reproduction. (apomixis via nucellar embryony); Mutations lead to new varieties of sweet oranges (Xu Q et al., Jan 2013. Andrés, 2013) The orange is a hybrid of pomelo (Citrus maxima) and mandarin (Citrus reticulata). The chloroplast genome, and thus the maternal line, is pomelo (Velasco et al., 2014). The sweet orange's entire genome has been sequenced (Xu Q et al., Jan 2013).

The sweet orange was first mentioned in Chinese literature in 314 BC, and it originated in a region that included Southern China, Northeast India, and Myanmar (Morton, 1987; Talon et al., 2020). (Xu Q et al., 2013). In 1987, orange trees were discovered to be the world's most cultivated fruit tree (Morton, 1987). In tropical and subtropical areas, orange trees are widely planted because of their sweet fruit. Orange tree fruit can be consumed raw or processed for its juice or fragrant peel. (Ali et al, 1976). Approximately 70% of citrus production in 2012 was sweet oranges (Hussain et al., 2021).

Brazil contributed 22% of the total global orange production in 2019 (79 million tonnes), followed by China and India. (Inglese & Sortino, 2019).

2.2.1 Nutritional Value

The orange flesh has a water content of 87%, 12% carbs, and 1% protein. Each 100 gram serving of orange flesh has 47 calories and 64% of the daily value of vitamin C. Other micronutrients do not exist in significant quantities. A navel orange (140g) contains 16.5 grams of carbohydrates and 73 calories.

Fresh orange juice has a water content of 88%, 26 g of carbohydrates (including 21 g of sugar), 2 g of protein, 0.5 g of dietary fiber, and 0.5 g of fat per cup (248 g or 8 oz). A cup has 112 calories, 149% of the daily value (DV) for vitamin C, potassium, thiamin, and folate. (11-19% DV). Oranges contain a lot of fiber; one medium-sized orange has 11% of your daily needs. In addition to helping you maintain a healthy weight and reducing your risk of diabetes, heart disease, and some types of cancer, dietary fiber has a number of other benefits (Kaczmarczyk et al., 2012). Phytonutrients in oranges can also reduce the risk of cardiovascular disease (Gupta et al., 2014)

2.3 Grapefruit

Citrus paradisi (grapefruit) is a subtropical citrus tree with large, sour to semi-sweet, and slightly bitter fruit. (Morton, 1987). Inside, the flesh is segmented, and the colors range from pale yellow to dark pink. Grapefruit is a citrus hybrid that originated in Barbados. It is the result of an unintentional cross between the sweet orange (*C. sinensis*) and the pomelo (*C. maxima*), which were introduced from Asia in the 17th century (Carrington and colleagues, 2003). It has also been called the forbidden fruit. It was previously known as the pomelo, but that name is now mostly used to refer to Citrus maxima (Li et al., 2010).

Grapefruit (pomelos) production worldwide in 2019 was 9.3 million tonnes, with China accounting for 53%. Vietnam, the United States, and Mexico are also significant producers.

2.3.1 Nutritional Value

A serving of 230 grams contains 97 calories, 202.54 grams of moisture, 1.77 grams of protein, 0.32 grams of total fat, 1.83 grams of ash, 24.52 grams of carbohydrate, 3.7 grams of total dietary fiber, 15.85 grams of sugar, 8.07 grams of sucrose, 3.7 grams of glucose, and 4.07 grams of fructose. It has 79.78% vitamin C, 65.28% lycopene, 19% vitamin A, 18.86% carbohydrate,

12.06% vitamin B5, 9.38% vitamin B6, 8.25% vitamin B1, 8.22% copper, and 7.50% vitamin B9 (USDA, 2018).

2.3.2 Red Grape Fruits

The sour white and pink grapefruits that had arrived on US soil in the 1800s did not impress Americans. The locals did not find the grapefruits sweet enough, despite the fact that the climate in Florida and South Texas was perfect for raising beautiful grapefruit orchards.

In 1929, a citrus grower discovered a stunning grapefruit mutation in a small orchard in South Carolina. Florida. Texas. It was much sweeter and had deeper red flesh. So the Ruby Red was born, and within five years, the Texas grapefruit industry exploded, focusing solely on red grapefruit and discarding pink and white varieties (Ron, 2020).

2.3.2.1 Nutritional Value

A 100-gram serving has 42 calories, 0.77-gram protein, 0.14-gram total fat, 10.66-gram carbohydrate, 1.6-gram total dietary fiber, and 6.89-gram sugar. It is high in vitamin C (35%), protein (7%), vitamin A (6%), carbohydrate (4%), total dietary fiber (6%), calcium (2%), iron (0%), and potassium (3%) (Fatsecret Platform, 2008). Red grapefruits are also high in potassium, which helps to counteract the negative effects of sodium.

2.3.3 White Grape Fruits

White grapefruits, which are indigenous to the West Indies, were produced by a natural cross between a pummelo and a sweet orange, both of which were imported from Asia in the 17th century. Many citrus trees were planted by European settlers throughout the West Indies; over time, many of these trees naturally cross pollinated, giving rise to new fruits such as the White grapefruit (Mangan et al., 2011). Because new varieties appeared at random, much of the grapefruit history was unrecorded, but the first record of the variety was made by a Welsh explorer on the island of Barbados in the late 18th century. In 1823, Odet Philippe, a Frenchman, brought white grapefruits to the United States and planted them in Florida. When red grapefruits were discovered, Texas stopped growing white grapefruits in 1962, relegating the pale-fleshed fruits to Florida and a few areas of California. Today, white grapefruits are primarily found in specialty s, home gardens, grocer and farmer's markets in the United States. The fruits are also grown in Mexico, South America, Morocco, Spain, Israel, and Caribbean areas.

2.3.3.1 Nutritional Composition

33 calories, 0.69 grams of protein, 0.1 grams of total fat, 8.41 grams of carbohydrate, 1.1 grams of total dietary fiber, and 7.31 grams of sugar are present in a 100-gram serving. It contains 7% protein, 1% vitamin A, 3% carbohydrate, 4% total dietary fiber, 1% calcium, 0% iron, and 3% potassium in addition to 37% vitamin C. White grapefruits are high in antioxidant, vitamin C, which boosts the immune system, stimulates collagen production in the skin, and has anti-inflammatory properties. Fiber is also abundant in the fruits, which helps to regulate the digestive tract, potassium, which helps to balance fluid levels, and have low levels of zinc, calcium, magnesium, iron, and copper (Fatsecret Platform, 2008).

2.4 Lemon

Citrus limon is a small evergreen tree that is native to Asia, specifically Northeast India (Assam), Northern Myanmar, and China. (Morton, 1987).

The tree's ellipsoidal yellow fruit is used all over the world for both culinary and non-culinary purposes, most notably for its juice, which has culinary and cleaning applications (Morton, 1987). Both the pulp and the rind are used in cooking and baking. Citric acid (5% to 6%) is present in lemon juice. It has a sour taste and a pH of around 2.2. Lemon juice is a popular ingredient in beverages and desserts such as lemonade and lemon meringue pie due to its distinct sour flavor. Genoa saw the beginning of significant lemon cultivation in Europe in the mid-15th century. Later, in 1493, when Christopher Columbus brought lemon seeds to Hispaniola on his voyages, the lemon was introduced to the Americas. The Spanish conquest of the New World aided the spread of lemon seeds. It was primarily used as a decorative and medicinal plant. (Morton, 1987). Lemons were increasingly planted in Florida and California during the nineteenth century (Morton, 1987).

Despite the fact that vitamin C was not yet recognized as an important dietary ingredient, James Lind's experiments on scurvy-stricken seamen in 1747 included adding lemon juice to their diets. (Morton, 1987).

2.4.1 Nutritional Value

Aside from their sour taste, lemons are high in nutrients, vitamins, and minerals. A 212-gram serving of lemons contains 112.4 mg of Vitamin C, 1.27 mg of Iron, 5.9 g of Total Dietary Fiber, 19.76 g of Carbohydrate, 0.17 mg of Vitamin B6, 0.078 mg of Copper, 0.403 mg of Vitamin B5, 0.085 mg of Vitamin B1, 293 mg of Potassium, 23 g of Vitamin B9, 55 mg of Calcium, 34 mg of Phosphorus, 2.33 g of Protein, and 17 mg (USDA, 2018). Lemons have been used for centuries to treat vitamin C deficiency. The British Navy discovered in the late 1700s that eating lemons and oranges could cure scurvy, a disease caused by a deficiency in vitamin C. Scurvy is now a rare disease in developed countries, thanks to the fact that it can be prevented with as little as 10 mg of vitamin C (and a single lemon contains more than 30mg) (Sauberlich et al., 1997).

2.5 Citrus Waste

In order to produce their juices, which are the most consumed fruit juices in the world, nearly one-fifth of all Citrus cultivars are subjected to industrial processes (FAO, 2021). This results in significant processing waste (about 120 million tons per year) (Chavan et al., 2018; Zema et al., 2018). However, this industrial process only uses 45% of the total fruit weight, leaving the remainder, such as peel (flavedo; 27%), pulp (albedo and endocarp; 26%), and seeds (2%), to be discarded (Leporini et al., 2021). Furthermore, whole fruits that don't conform quality requirements and are thus discarded increase these amounts.

To improve fruit quality or remove tree branches, pruning is a common practice that implies the production of a lot of leaves. (Leporini et al., 2021), a residue that adds to the already large amount of Citrus waste. This is frequently thrown into landfills or rivers, causing pollution or contamination of water and depletion of dissolved oxygen levels, particularly in developing countries. Citrus waste pollutes the environment significantly. Because it is abundant, chemically complex, and biodegradable, its easy fermentability necessitates a high oxygen demand. It has a low pH (3-4), a high water content (80-90%), and a high organic matter content (95% of total residue) (Flotats and Ruiz, 2014).

Citrus fruit waste is also disposed of through combustion to obtain thermal energy (Siles et al., 2016), a dangerous procedure that releases high levels of nitrogen, carbon, and sulfur oxides into the environment, making it no longer a suitable strategy for Citrus fruit waste disposal.

As a result, several alternatives for better control of Citrus fruit waste were proposed, such as the manufacturing of fortified animal feeds, the use of fiber-rich components in confectionery products, the extraction of macro and micronutrients, as well as the production of organic fertilizer, biofuels, enzymes, and ethanol, which are used in the food, pharmaceutical, and cosmetic industries (Chavan et al., 2018; Osorio et al., 2021; Siles et al., 2016).

2.5.1 Composition of Citrus Waste

Citrus fruit byproducts, such as seeds, pressed pulp, exhausted peel, secondary juice (obtained by pressing the remaining pulp after primary juice extraction), and leaves, contain proteins, dietary fibers (pectin and cellulose), lipids (linoleic, oleic, palmitic, and stearic acids), organic acids, and sugars (glucose, sucrose, and fructose) (i.e., limonene and linalool) (Mahato et al., 2018). The molecular composition of each by-product varies according to cultivar, cultivation method, harvesting time, and degree of ripeness of the fruit.

After juice extraction, citrus fruit peels make up nearly half of the wet fruit mass. (Sharma et al., 2017), and are particularly rich in aromatic compounds, dietary fibers, pectin, natural pigments, and polyphenols (Rafiq et al., 2018). Citrus peel is primarily used for essential oil extraction, which can be found in the oil sacs of both cuticles and peels, though they can also be isolated in much smaller quantities from seeds or leaves. Essential oils are composed of monoterpenes and sesquiterpenes (hydrocarbons with two or three isoprene units in their structure) and oxygenated derivatives (i.e., alcohols, ketones, aldehydes and esters). There has long been a use for citrus essential oils as flavorings in food, cosmetic, and pharmaceutical products and have just recently had their health-promoting qualities reevaluated (Dosoky and Setzer, 2018; Bruni et al., 2019).

Citrus fruit peels are high in pectin and dietary fibers, which are also found in juice and pulp (Dimopoulou et al., 2019). Pectin, complex polysaccharide that is partially esterified with methanol or acetic acid and is composed of D-galacturonic acid units linked by -1,4 glycosidic bonds. It is commonly found in insoluble or complex forms, ranging in color from white to light brown, and is used as a texturizer, thickener, emulsifier, and stabilizer in the preparation of confectionery, jams and jellies, as well as biodegradable products. Dietary fibers are non-starch polysaccharides with at least ten carbohydrates units that are difficult to digest.

Citrus wastes are high in carotenoids and flavonoids, which are also found in citrus peels. Carotenoids are pigments that are biosynthesized in various fruits and vegetables. They are

precursors of vitamin A, which is involved in epithelial tissue growth, immune system strengthening, and proper vision function (Widjaja-Adhi et al., 2018).

Flavonoids are classification of secondary metabolites. that plants produce to protect themselves from ultraviolet radiation or pathogenic injury. Citrus flavonoids have been extensively researched for their anti-cancer, anti-inflammatory, and neuroprotective properties (Cirmi et al., 2016). (Cirmi et al., 2016). The same quantity of phenolic acids, which have a high level of free radical scavenging activity, are present (Kim and Kim, 2016). (Kumar and Goel, 2019). A good source of oil, proteins, limonoids, and phenolic compounds, especially the flavonoids eriocitin and hesperidin, are found in the seeds that are isolated during juice extraction. (Rosa et al., 2019).

2.6 Dietary Fiber

Dietary fiber, which is often divided into insoluble and soluble dietary fiber, is composed of a mixture of plant carbohydrate polymers, both oligosaccharides and polysaccharides, such as cellulose, hemicelluloses, pectin substances, gums, resistant starch, inulin, and some non-carbohydrate moiety (Fuentes-Zaragoza et al., 2010). A few sources of dietary fiber. (% dry matter) are shown in Table 1. To be considered a food ingredient, the fiber source should have an SDF/IDF ratio close to 1:2. (Jaime et al., 2002). Dietary fiber not only helps to avoid hydrolysis, digestion, and absorption in the human small intestine, but it also performs the following functions: fecal bulking efficiency, colonic fermentation enhancement, insulin level maintenance, and pre-prandial cholesterol reduction (Champ et al., 2003, Fuentes-Zaragoza et al., 2010). Dietary fiber supplementation can result in safer and more affordable foods with multiple health benefits. The average daily fiber requirement for women is 21-25 g per day and 30-38 grams per day for men (Food and Nutrition Board, Institute of Medicine, 2001). Soluble fiber should account for 20-30% of our daily fiber intake, according to most nutritionists and diet experts. Aside from health benefits, dietary fiber contains functional properties such as water holding capacity, oil holding capacity, viscosity or gel formation, bile acid binding capacity, emulsion stabilization, and shelf-life enhancement. Daily production of large quantities of cereal, vegetable, and fruit byproducts can be used to make products with added value. In addition to providing dietary fiber, they also contain bioactive substances like polyphenols and essential oils that are advantageous to both the producer and the consumer. One typical example is the waste left over after processing citrus peel commercially. (Braddock, 1999). In order to replace the fat in dry fermented sausages, Garcia et

al. (2002) suggested adding cereal or fruit fiber, specifically 1.5% orange fiber. Citrus fiber can be used as efficient lipid oxidation inhibitors in meat products, enhancing oxidative stability and extending shelf life because it contains polyphenol-like components and has bioactive properties (Fernandez-Gines et al., 2003). Citrus fiber could be used to reduce residual nitrite levels as well (Fernandez-Gines et al., 2003). Citrus peel could be considered a potential source of pectin, which is made up of white spongy and cellulosic fibers. (Terpstra et al., 2002Dietary fiber consumption is associated with a lower risk of life-threatening chronic diseases such as bowel, gastrointestinal disorders, obesity, diabetes, cardiovascular disease, and cancer, as well as promoting physiological functions such as blood cholesterol reduction and glucose attenuation (Figuerola et al., 2005). Citrus peel can lower plasma liver cholesterol, serum triglyceride levels, serum total cholesterol, liver total lipids, and liver cholesterol, according to a number of epidemiological studies (Terpstra et al., 2002). The fiber in orange fruit peels aids in enhancing intestinal health and function. (2005) Chau et al. Due to their high physicochemical properties, citrus hystrix and citrus maxima (red and white varieties) peel, pulp, and peel fiber could be used as potential dietary fiber sources in food enrichment.

Table 2.1: Dietary fiber sources (% dry matter).

Sources of Fiber	Total dietary Fiber Contents	Analytical methods	References
Lime peel	66.7 - 70.4	Enzymatic chemical method: NSP + Klason lignin	Figuerola et al., (2005)
Orange Peel	64.3	Enzymatic gravimetric method	Figuerola et al., (2005)
Grapefruit peel	44.2 - 62.6	Enzymatic gravimetric method	Figuerola et al., (2005)
Limon Peel	60.1 - 68.3	Enzymatic gravimetric method	Figuerola et al., (2005)

Fruit remnants, which are typically thrown away as waste, should be considered as a potential source of nutraceuticals because of their accessibility and low cost, which makes them a viable option for significant low-cost nutritional dietary supplements. These unwelcome manufacturing byproducts, which are high in bioactive compounds, could be recycled as dietary fiber and polyphenol-rich value-added food supplements. They function as non-caloric bulking agents, enhance water and oil retention, enhance emulsion, and may guard against diseases brought on by oxidative stress. Fruit peel extracts have potential in the food industry as sources of bioactive compounds. The pollution brought on by improper disposal of such residues would also be reduced by the widespread use of citrus peel.

2.7 "Junk" Food

"Junk" food is used to describe food that contains a lot of calories from fat, sugar, and possibly sodium., but low in, vitamins, dietary fiber, minerals, protein, and other important nutritional value (O'Neill, 2006). It is also known as HFSS food (high in fat, salt, and sugar) (Parks, 2016).

Precise definitions vary depending on the context and over time. Some high-protein foods, such as saturated-fat meat, may be considered junk food (Scott, 2018). Despite the fact that fast food

cannot be categorically categorized as "junk" food, fast food and fast food restaurants are frequently associated with "junk" food (Smith, 2000). Almost all "junk" food is heavily processed.

Concerns about the harmful health effects of a diet high in "junk" food, particularly obesity, have led to public health awareness campaigns and restrictions on advertising and sale in a number of nations (Surya et al., 2020)

Excess fat, simple carbohydrates, and processed sugar found in junk food contribute to an increased risk of obesity, cardiovascular disease, and many other chronic health conditions when consumed frequently (Furham, 2018). An analysis of fast food consumption in Ghana revealed a connection between the prevalence of obesity and junk food consumption. According to the report, obesity has resulted in complex health issues such as an increase in the rate of heart attacks (Searcey & Richtel, 2017). According to research, arteries can begin to clog as early as the age of 30, laying the groundwork for future heart attacks (Arya et al., 2013). Consumers also overeat in one sitting, and those who have had their hunger satisfied with "junk" food are less likely to consume healthy foods such as fruits and vegetables (Carolyn et al., 2007),

Testing on rats has revealed that "junk" food has negative effects that may manifest similarly in humans. Eating "junk" food alters brain activity in a way that addictive substances like cocaine and heroin do, according to a 2008 Scripps Research Institute study. After many weeks of unlimited access to "junk" food, the pleasure centers in rats' brains became desensitized and needed more food to feel satisfied; when the "junk" food was taken away and replaced with a healthy diet, the rats starved for two weeks instead of consuming wholesome food (Johnson et al., 2010. Goodwin, 2010). According to a 2007 study in the British Journal of Nutrition, pregnant female rats who consumed "junk" food were more likely to produce offspring with unhealthy eating habits (Surya, 2020).

Eating "junk" food can have a detrimental effect on energy levels and emotional wellbeing, according to other studies on the effects of sugary foods on human emotional health. (Surya, 2020).

In a study published in the European Journal of Clinical Nutrition, the frequency of consumption of 57 foods/drinks by 4,000 children aged four and a half was collected by maternal report. When the children were seven years old, they were given the Strengths and Difficulties Questionnaire (SDQ), which has five scales: hyperactivity, conduct problems, peer problems, emotional symptoms, and pro-social behavior. Then, in 33% of the subjects, an increase in "junk" food

consumption of one standard deviation was associated with excessive hyperactivity, suggesting that young children who consume too much junk food are more likely to fall into the top third of the hyperactivity scale. "Junk food" had no statistically significant correlation with the other scales (Wiles et al., 2007).

Some examples of “junk” food include:

- cakes and biscuits
- fast foods (such as hot chips, pizzas, and burgers)
- chocolate and sweets
- processed meat (such as bacon)
- snacks (such as chips)
- sugary drinks (such as sports, energy and soft drinks)
- alcoholic drinks

2.7.1 Effects of “Junk” Food on Health

2.7.1.1 Obesity

Obesity is the new millennium's emerging pandemic. This has far-reaching public health implications, as 70% of overweight children grow into overweight adults. Adult obesity is defined as having too much body fat as determined by the BMI ratio which is calculated by dividing the kilogram weight by the square of the height. Adults with BMIs greater than 25 are considered overweight, and those with BMIs greater than 30 are considered obese (classes I, II or III or moderate, severe or morbidly obese). According to Swaminathan, being overweight is defined as weighing between 15% and 25% more than the average, while being obese is defined as weighing more than that. Obesity has increased in developed and developing countries, though at varying rates and patterns. It has serious public health implications because 70% of overweight children grow up to be overweight adults. In people who are prone to addictive behavior, the combination of fat and sugar can cause a dopamine-driven surge of intense pleasure. However, it should be mentioned they are also harmful to one's health. High fat content, particularly cholesterol, sugar, and salt, has a negative impact on health. Sugar's high calorie content can lead to obesity (Arya et al., 2013).

2.7.1.2 Diabetes

Type 2 diabetes is the most prevalent form. It is a severe condition that makes it impossible to control blood glucose (sugar). There are two reasons for this. The body's cells first develop an insulin resistance (insulin resistant). In order for glucose (blood sugar) to travel from the blood into the cells, where it is used as fuel for energy, insulin acts as a key. There is an excess of sugar in the blood when cells become insulin resistant because it takes more and more insulin to transport sugar into the cells. Over time, if the cells need more and more insulin, the pancreas cannot keep up and eventually fails (Song, Y. 2016).

2.7.1.3 Lack of Energy

"Junk" foods are devoid of essential nutrients. The ingredients in junk food do not supply useful energy. When one consumes junk food, one feels weak and has less energy.

2.7.1.4 Poor Concentration

High levels of vegetable oil that has been hydrogenated can be found in "junk" food. It is challenging for our digestive system to digest. To digest it, a lot of blood and enzymes are needed. As a result, the intestine receives a significant amount of blood. As a result, one feels sleepy and lethargic, and their ability to concentrate is compromised.

2.7.1.5 Heart Diseases

Low density lipoproteins are found in "junk" food. A high cholesterol level in the blood reduces the supply of oxygen to the blood and the heart. The inner lining of blood vessels becomes clogged with cholesterol over time, making the heart work harder to pump blood through them. Heart weakness results as a result. Cardiac arrest and atherosclerosis are brought on by plaque buildup.

2.7.1.6 Blood Pressure and Renal Failure

Sugar and salt are abundant in junk food. Excess sodium ion concentration raises blood pressure and causes renal failure.

2.7.2 Effects of Dietary Fiber on Junk Foods

Any diet that promotes heart health must include fiber, especially soluble fiber. By reducing LDL (bad) cholesterol, a high-fiber diet can lower cholesterol levels. The risk of metabolic syndrome, a collection of risk factors linked to coronary heart disease, diabetes, and stroke, can also be decreased by consuming a high-fiber diet. Additionally, fiber can aid in lowering blood pressure, decreasing inflammation, raising HDL (good) cholesterol levels, and reducing belly fat (Dinu et al., 2017).

CHAPTER THREE

3.0 MATERIAL AND METHOD

3.1 Material Procurement

The orange, red grape and lemon fruits were purchased from Ketu market, Lagos State, Nigeria. Ingredients for the preparation of junk foods; wheat flour, sugar, margarine, eggs, baking powder, vanilla flavor powder, milk, baker's yeasts, vegetable oil, beef, intestine and seasonings were purchased from Ibafo market, Ogun state, Nigeria. The chemicals used for the analysis was of analytical grade.

3.1.1 Equipment

Juice extractor, Oven, Laboratory milling machine, stirrer, weighing balance, warring blender, dicer, spoons, conical flasks, beakers, pipette, burette, retort stand, measuring cylinders, kjeldahl apparatus, kjeldahl tablet, crucibles, tins, Soxhlet apparatus, micropipette, UV-Visible Spectrophotometer (Jenway 7205), and centrifuge. spatula, nose mask, hand gloves, sample bottle rack, petri dishes, sample bottles, Eppendorf tubes, distilled water

3.2 Extraction of citrus fiber and pith from citrus fruits waste

The fruits were thoroughly washed to remove dirt and adherent extraneous materials before being peeled by hand with a sharp kitchen knife. Kitchen juice extractor was used to extract the juice and the seed removed. The pulp and the fiber was extracted and sieved with muslin cloth to remove excess juice and then sun dried to a lower level of moisture content after which it was oven dried at 60℃ for about 3-4 hours and cooled and then milled in laboratory mill with have a sieve of 0.8mm to obtain the fiber in powdered form. The ratio of the citrus waste fiber was built using the mixture response surface methodology (MRSM) to determine the proportion of Orange fiber, White grape fiber, Red grape fiber, Lemon fiber respectively based on the relative abundance of each citrus waste during the season as in Table 3.1.

Table 3.1: Ratio of the citrus waste fiber powder

Sample	Orange Fiber	White grape fiber	Red grape fiber	Lemon fiber
A	60%	20%	10%	10%
B	60%	20%	10%	10%

A-Mixture of Segment wall (inner fiber); B-Mixture of pith (whitish spongy part)

3.3 Phytochemical analysis

3.3.1 Determination of phytate

For phytic determination, the Wheeler and Ferrel (1971) method was used. For 3 hours, two grams (2.0 g) of each sample (finely ground) were dissolved in 100 mL of 2% HCl (v/v) and filtered. The filtrate (25 mL) was mixed with 5 mL of 0.03% NH4SCN solution as an indicator and 50 mL of distilled water in a 100 mL conical flask. Titration was performed using ferric chloride solution .$Fecl_3$ = 0.00195g/ml. Therefore 0.2g = 100ml standard flask

% Phytic acid = $\frac{Titre\ value \times 0.0019}{2} \times 100$

3.3.2 Determination of oxalate

The Day and Underwood (1986) method was used. Each sample was weighed into a 100 mL conical flask, 75 mL of 3 M H2SO4 was added, and the solution was stirred intermittently with a magnetic stirrer for about 1 hour before being filtered through Whatman No 1 filter paper. Approximately 25 mL of the filtrate was collected and titrated hot (80 - 90^{o}C) against 0.1 M KMnO4 solution for at least 30 seconds until a faint pink color appeared.

Oxalate $(mg/g) = V_T \times 0.9004$

Where, V_T = Titre volume (mL)

3.3.3 Determination of Phenol

The approach used by Keay et al. in 1964 was applied. For the purpose of extracting the phenolic components, 0.5 g of the sample was weighed and boiled with 50ml of ether. Pipette 5ml of the extract into a 50 ml flask. 0.1N NH4OH (ammonium hydroxide), 2 cm^3, and 5 ml of concentrated amyl alcohol were added to 100 ml of distilled water. After that, wait for color development for 30 minutes. It was determined the optical density at 505 nm.

Preparation of Standard tannic acid

The exact amount of 0.1g of tannic acid was dissolved in 100ml of distilled water in a standard flask with a 100ml capacity (1 mg/cm^3)

A range of concentrations (0.2-1.0mg/cm^3) were prepared for the standard curve. Five milliliters of the standard tannic acid were pipetted into various test tubes at various concentrations. Each test tube received 2 cm3 of NH4OH, 5 cm3 of amyl alcohol, and 10 cm3 of distilled water.

3.3.4 Determination of Alkaloid

The alkaloid content was determined using Harbone's (1973) method. A 250ml beaker was filled with 2.5g of the sample. 100ml of 10% acetic acid was mixed with 20ml of ethanol in a 250ml beaker containing the sample. For 4 minutes, the beaker was left standing. The result was filtered. The extract was concentrated to one-quarter of its original volume in a water bath. Concentrated ammonium hydroxide was added to the extract drop by drop until precipitation was complete. Before filtering, the precipitation was collected and washed with dilute Ammonium hydroxide. The leftovers were weighed and dried.

$$\%\text{Alkaloid} = = \frac{\text{weight of alkaloid}}{\text{weight of sample}} \times 100$$

3.3.5 Determination of Tannis

Harbone (1973) described the method that was used. After accurately weighing 0.5g of the sample into a conical flak, 75ml of distilled water was added and boiled for 30 minutes. Filtered into a 100ml measuring flask and marked with distilled water to volume. 1ml of the solution was poured into a conical flask, followed by 1ml of Ferric chloride reagent and 8ml of distilled water. 1ml of standard was added to the tube to make the standard. 1ml of reagent Fecl3 solution was mixed with 8ml of distilled water. At 540nm, the absorbance of unknown and standard against blank was measured. The tannin concentration was calculated

$$.C\ \text{unknown} = A\ \text{unknown} \times \frac{C\ \text{standard}}{A\ \text{standard}}$$

A = Absorbance, C = Concentration

3.3.6 Determination of Flavonoids

The total flavonoid content was determined using a modified colorimetric method. In a test tube, a suitable amount of extract was mixed with distilled water. Then 5% NaNO2 was added, followed by 10% AlCl3, then 1 M NaOH after another 5 minutes, and finally distilled water. After 15 minutes, the absorbance at 510 nm was measured against a blank. The standard curve was created by varying the catechin concentration. The flavonoid content was calculated in terms of grams of catechin equivalents (CE) per 100 grams of dry weight (dw).

3.4 Determination of Soluble and Insoluble Dietary fiber

3.4.1 Determination of Total Dietary Fiber

The Lee et al., 1992 method was applied. A 50 ml centrifuge tube was filled with 1g of the sample, 2ml of dimethyl sulphoxide, and a cap. To homogenize the mixture, it was stirred on a magnetic stirrer for about 2 minutes. The tube was then placed in a beaker of boiling water on a hot plate with a stirrer. After one hour of mixing, the tube was removed without allowing the mixture to cool. Eight milliliters of sodium acetate buffer with a pH of 5.2 was then added and vortexed. Until the mixture cooled to between 30°C and 40°C, the tube was kept at room temperature at about 35°C. Pullulanase solution was added in 0.1 ml increments after 0.5 ml of -amylase solution.

After capping the tube, it was incubated for 16 hours while being continuously mixed for the first hour. 40ml of ethanol was added, thoroughly mixed by inversion, and then left at room temperature for an hour. The mixture was centrifuged at 1500g for 10 minutes before having as much of the supernatant as possible removed by decantation without disturbing the remaining material. The residue was twice washed with 50ml of 85% ethanol each time. The residue was then mixed by inversion on a magnetic stirrer to suspend it, and the supernatant was once again removed. The residue was washed with 40ml of acetone, which was then stirred for 5 minutes and centrifuged at 1500g for 10 minutes. The tube was placed in a beaker of water heated to 65°C on a stirrer hot plate with the contents continuously stirred to mix well until the residue appeared dry after the supernatant liquid was aspirated out and discarded.

$$\%Total\ \ dietary\ fiber = \frac{weight\ of\ residue}{weight\ of\ sample} \times 100$$

3.4.2 Determination of Soluble Dietary Fiber

Lee 1992 provided a description of the procedure. The residue of Total Dietary Fiber was heated to 70°C and washed with 10ml of distilled water. In a 500 ml beaker, the filtrate and washing were collected. The soluble dietary fiber was precipitated using 4 280 ml of a 95% ethanoic solution that had been heated to 60 °C.

The precipitate was allowed to form for an hour. A suction crucible and suction pump were used to filter the precipitate. The residue in the crucible was washed three times with 30ml each of 78% ethanol, 95% ethanol, and acetone to get rid of any remaining traces of lipids.

The crucible + residue was dried overnight at 103℃ in an air- dry Gallenkamp oven.

$$\%\, SDF \;=\; \frac{\text{Weight of crucible} \;+\; \text{residue} - \;\text{weight of empty crucible}}{w\text{eight of sample}}\; X\; 100$$

3.4.3 Determination of Insoluble dietary fiber

Insoluble dietary fiber was determined by the difference of %TDF and %SDF.

%IDF (INSOLUBLE DIETARY FIBER) = %TDF - %SDF.

3.5 Determination of in vitro Antioxidant potentials

3.5.1 Determination of DPPH radical scavenging activity

The method for determining the extract's capacity to scavenge DPPH radicals was described by Mensor et al (2001). Sample stock solutions (1.0 mg/ml) were diluted with methanol to final concentrations of 250, 125, 50, 25, 10, and 5 g/ml. 2.5 ml of the extract or standard solution were combined with 1 ml of the 0.3 mM DPPH methanol solution, and the mixture was left to react for 30 minutes at room temperature. The mixture's absorbance was calculated using the formula for percentage antioxidant activity (AA%) at 518nm.

$$:AA\% = 100 - [(Abs\ sample - Abs\ blank) \times 100]/Abs\ control$$

3.5.2 Determination of FRAP

According to Pulido, Bravo, and Saura Calixto (2000), the citrus fiber sample's capacity to reduce Fecl solution was used to ascertain this fiber's reducing property. 2.5ml, 200Mm sodium phosphate buffer (PH6.6), 2.5ml of 1g/100ml potassium ferrocyanide, and 1ml of the sample aliquot (0.5g of the sample homogenized in 20ml ethanol) were combined. The mixture was incubated at 50°C for 20 minutes before 2.5ml, 10ml/100ml potassium ferrocyanide was added. After adding trichloroacetic acid, the mixture underwent a 10-minute centrifugation at 650 rpm. The absorbance at 700 nm was measured after 2.5 ml of supernantant, equal parts water, and 0.5 ml of ferric chloride were combined. A higher absorbance denotes a higher reducing power.

3.6 Functional Properties of citrus waste dietary fiber

3.6.1 Determination of Water and Oil Absorption

The Kinsella 1976 procedure was followed. 1 gram of sample was weighed into a clean centrifuge tube and thoroughly mixed with 10 ml distilled water or oil for 30 seconds using a stirring rod. The sample was allowed to stand at room temperature for 30 minutes before being centrifuged at 3500rpm for 30 minutes. The volume of the supernatant for water and oil absorption was read from the graduated centrifuge tube after centrifugation. By multiplying the density of oil (0.894g/ml) and water (1g/ml), the absorbed water was converted to weight (in grams). The capacities for oil and water absorption were expressed in grams of oil and water absorbed per gram of sample.

3.6.2 Determination of Bulk Density

The method described by Akpata and Akubor (1999) was used. In a calibrated measuring cylinder, ten grams of sample were weighed. The cylinder's bottom was then repeatedly tapped onto a firm pad on a laboratory bench until a constant volume was observed. The dense volume was captured. The bulk density is calculated as the sample weight divided by the volume of the sample after tapping.

$$\text{Tapped Bulk density} = \frac{\text{weight of sample (g)}}{\text{sample (ml)}}$$

$$\text{Loose bulk density} = \frac{\text{weight of loosely pack (g)}}{\text{volume of sample (ml)}}$$

3.6.3 Determination of Dispersability

About ten grams of sample was weighed into 100 ml measuring cylinder, distilled water was added to each volume of 100ml. The sample was stirred vigorously and allowed to stand for three hours. The volume of settled particles was recorded and subtracted from 100. The difference is reported as percentage Dispersability.

%Dispersability = 100 – volume occupied by the flour.

3.7 Production of "Junk" Foods

3.7.1 Production of Cakes

Cakes were made with a slight modification of the standardized recipe and method provided by Sharoba et al., 2013. 200g whole wheat flour, 200g margarine, 150g sugar, 5 eggs, 4.2g baking powder, and 4.2g vanilla extract, the butter and sugar was weighed into the mixer bowl and mixed until smooth like cream, mixed a well-blended egg and vanilla extract in a plastic container. The wheat flour and baking powder were mixed together with the egg mixture was simultaneously added to the mixed butter and sugar. The dough was transferred to a greased pan after the mixture was whipped until smooth. The citrus fiber-fortified cake was made by replacing the wheat flour with 10% citrus fiber and the Margarine with 5% citrus fiber, mixing all ingredients together, and transferring the dough to a greased baking pan. Both pans were baked for 20min. at 150±5^{o}C then was cooled at room temperature. Cakes were prepared according the formula is shown in Table 3.1.

Table 3.2 Recipe for Cake and Doughnut

Ingredients	**Weight (g)**	
	Cake	**Doughnut**
Wheat flour	200	250
Margarine	200	25
Sugar	150	25
Eggs	5 small sizes	2 small sizes
Baking Powder	4.2	-
Vanilla	4.2	-
Yeast	-	3.5
Water	-	70 ml
Nutmeg powder	-	A pinch

3.7.2 Production of Doughnut

Doughnuts were made with slight modification of the standardized recipe in Table 3.7.1 and method provided by Dawood et al., 2015. The ingredients were mixed in a small mixing bowl, yeast and sugar were combined with 5 tablespoons of warm water. The bowl was covered and placed in a warm location to rise, double, and form small bubbles. The dry ingredients and margarine were combined in a large mixing bowl. The beaten egg, yeast batter, and water were added and thoroughly mixed for about 10 minutes. The sticky dough was folded into a rough ball and covered with a clean nylon for about an hour, or until it doubled in size.

After the dough had risen, it was placed on a floured surface, flattened with the palm, and a small amount of flour was rubbed on the sticky flattened dough. To make a large doughnut, the dough was cut into rounds and allowed to rise for about 20 minutes before frying. The oil was heated until it reached a temperature of 240°C. The oil test was carried out by dropping a small amount of dough into the oil to see how quickly it fried. Finally, the dough was fried in hot oil before being cooled and packaged. The citrus fiber-fortified doughnut was made by replacing the wheat flour with 10% citrus fiber and the Margarine with 5% citrus fiber, mixing all ingredients together, and frying the doughnut at 240°C, cooled and packaged.

3.7.3 Production of Ice cream

The following ingredients are used in production of ice cream; 125g of milk, 2.6g gelatin, 16.5g sugar, 60g whipping cream, 1.25g vanilla extract, 2 small eggs, 500g water. For citrus fortified ice cream 2% of the dietary fiber was added to enrich the ice cream. The milk was weighed into a pot, 500g of water was added and thoroughly mixed, and the milk was heated until it was scaling. After boiling, it was allowed to cool before being placed in the freezer. After cooling, it was transferred to the mixer bowl and mixed with the mixer; while mixing, homogenized gelatin, whipping cream, and sugar were added. The beaten eggs and vanilla extract were combined and added to the cream mixture, which was thoroughly mixed with a mixer. After thoroughly mixing, the cream was transferred to the freezer for about 15 minutes to cool before being mixed again and packaged into a packaging container and placed inside the freezer.

3.7.4 Production of Sausage

The production of beef sausage was produced using the following ingredients in Table 3.3 (Gedikoglu &Clarke, 2019). The connective tissues on the beef meat was removed and washed. The meat was minced using a meat mincer and weighed into a blender together with other ingredients and blended to a homogenize mixture. The slurry was stuffed into the casing (intestine), boiled for 4 minutes and then fried; it was then cooled and packaged.

3.8 Proximate Analysis

3.8.1 Determination of moisture content

Moisture content was determined by Moisture analyzer (OHAUS MB45). The moisture balance was switched on and set to drying temperature at 105^{o}C. The drying pan was placed on the balance and tare. 2g of the sample was spread uniformly on the pan. The balance was covered and the star button was pressed to commence drying. After drying the result was recorded.

3.8.2 Determination of ash content

Two grams of the sample was weighed into a crucible. Dry at 105°C; burn at low red heat for 15 minutes, ash in a muffle furnace at dull red heat (550°C-600°C for 15 minutes), remove from muffle furnace, cool briefly, place in desiccators until cold, and weigh. (AOAC, 2012).

Table 3.3: Recipe for sausage production

Ingredients	Quantity
Boneless beef	250 g
Curry powder	5 g
White pepper	5 g
Vegetable oil	25 g
Powdered milk	25 g
Wheat flour	25 g
Knorr cubes	10 g
Salt	5 g
Water	125 ml

$$\text{Calculation: \%ash} = \frac{B-C}{B-A} \times 100$$

Where; A = weight of empty crucible in g

B = weight of dish + sample before ashing

C = weight of dish + sample after ashing

(B-C) = lost in the weight of the sample after ashing

3.8.3 Determination of protein content

The macro Kjeldahl method was used to determine the crude proteins. In a Kjeldahl digestion flask, one KJELTAB® tablet and 1g of the substance were added. The digestion process took place in the fume cupboard digestion flask for an hour until a clear and light blue color was visible after 12 mL of strong sulfuric acid was added. In a 100 mL volumetric flask, the digest was cooled and diluted to the required concentration with distilled water. (Dilute with 70mL of distilled water and alkalize with 50mL of 40% w/v NaOH) Distil in an automatic distillation unit (nitrogen-free).The mixture was automatically distilled into 30 mL of a 4% w/v boric acid solution (with methyl red and bromocresol green indicators) (mix indicator 0.198g bromocresol green plus 0.132g Methyl red in 200 mL alcohol). The distillation process was then repeated until a volume of about 150 mL was reached and the boric acid solution's color changed from pink to yellowish-green. The solution in the conical flask was distilled, and then the endpoint was reached by titrating the solution against 0.1N hydrochloric acid. The same process was used to get a blank, but only with distilled water.The % Nitrogen (%N) and % crude protein (%CP) is determined using the equation below:

$$\%N = \frac{(Vs - Vb) \times C \times 1.4007}{W}$$

$$\%CP = \%N \times CF$$

Where Vs is the volume (mL) of standard acid used to titrate the sample to the endpoint, Vb is the volume (mL) of standard acid used to titrate the blank to the endpoint, C is the molar concentration (mol dm-3) of HCl used in four decimal places, W is the weight (g) of sample used, and CF is the sample conversion factor (6.25). The conversion factors are determined by the material being analyzed.

3.8.4 Determination of fat content

This was determined by employing the AOAC method (2012). 4g of dried sample was weighed into a fat-free thimble, lightly plugged with cotton wool, and extracted with n-hexane in a 5 hour soxhlet apparatus. The residue extract was evaporated for 30 minutes in an air oven at 100°C, cooled, and weighed. The fat content was calculated as;

$$\%\, fat = \frac{(weight\ of\ flask + fat\ ) - weight\ of\ empty\ flask}{original\ weight\ of\ sample} \times 100$$

3.8.5 Determination of Crude Fiber

The AOAC-recommended method was used to determine the crude fiber (2012). 200ml of 1.25% H2SO4 and 2g of the sample were added to a flask after being accurately weighed. For 30 minutes, the mixture was heated in a reflux environment. Through a fiber muslin cloth, the hot mixture was filtered. The obtained filtrate was discarded, and the remaining material was added back to the fiber flask along with 200 ml of 1.25% NaOH and heated for an additional 30 minutes. The residue was taken out and then put into the crucible. To remove the moisture, the crucible and the leftovers were oven dried for an entire night at 105°C. The residue-filled oven-dried crucibles were cooled in a desiccator before being weighed to determine the W1. W1-containing crucible was moved to the muffle furnace for four hours of ashing at 550°C. To obtain W2, the desiccator was used to cool the crucible containing white or grey ash (free of carbonaceous materials) and weigh it.
Weight of fiber is determined by the difference between W1 and W2.

$$\%\, fibre = \frac{w_1 - w_2}{original\ weight\ of\ sample} \times 100$$

W1 = Dried crucible + residue before ashing

W2 = Dried crucible + residue after ashing

3.8.6 Determination of carbohydrate content

The determination of carbohydrate in the samples was determined by difference. That is the values or percentages of moisture, ash, protein, fat and fibre was summed up and the obtained was subtracted from hundred which gives the carbohydrate content (AOAC, 2012).

3.9 Colour evaluation

L, a and b parameter was determined using a colorimeter. It assessed the following colour traits: L (lightness) axis – 0 is black, while 100 is white; a (red–green) axis – positive values are red, while negative values are green and 0 is neutral; b (yellow–blue) axis – positive values are yellow, while negative values are blue and 0 is neutral. Multiple measurements (triplicate) of L, a and b parameters was determined using the colorimeter on the sample. From the data obtained, deltachroma (ΔC), color intensity (ΔE), hue angle, and degree of whiteness was calculated according to equations 1, 2, 3 and 4, respectively (Hunt, 1991; Gonnet, 1999).

The values of hue angle ($H = \tan^{-1} b/a$) indicate sample color where hue angle 0^0 coincides with red color; 90^0 with yellow color, 180^0 with green color, and 270^0 with blue color (McGuire, 1992; Voss, 1992), whereas C is for metric chroma, the correlate of saturation ($C = (a^2 + b^2)0.5$), as described by Gonnet (1999).

$$\Delta C = (\Delta a^2 + \Delta b^2)^{0.5} \quad \ldots\ldots \quad (1)$$

$$\Delta E = (\Delta L^2 + \Delta a^2 + \Delta b^2)^{0.5} \quad \ldots\ldots \quad (2)$$

$$H = \tan^{-1} (b/a) \quad \ldots\ldots \quad (3)$$

$$W (\%) = 100 [(100- L)^2 + ((a)^2 + (b)^2)]^{0.5}. \quad \ldots\ldots \quad (4)$$

Note: W is the degree of whiteness of the sample

3.10 Microbial Analysis

3.10.1 Serial Dilution

The serial dilution was carried out in McCockney bottles, which were washed and dried in an oven at 121℃ for 30 minutes. Pipetting 9ml of distilled water into the bottles. The bottles were then sterilized in an autoclave for 15 minutes at 121o C at 15 psi. After allowing the bottles to cool, 1 ml of the sample was pipetted into the bottle to create the stock. 1ml of the stock was pipetted out

and into 9ml of distilled water to give 10^{-1}. The process was repeated until 10^{-3} was reached. This is no longer referred to as a sample, but rather as an inoculant.

3.10.2 Preparation of Media

The medium used to determine the presence of bacteria was Nutrient Agar. For the determination of fungi, the medium used was Potato Dextrose Agar (PDA) 23 g and 18.72 g of NA and PDA respectively were weighed into 500ml Durham bottle adding 500ml of distilled water. The mixture was homogenized by gently shaking it and then immersing it in a water bath. Once completely homogenized, the agar was allowed to cool but not solidify.

3.10.3 Isolation of bacteria

Sterile Petri-dishes were labeled by sample with each dilution factor. The cooled NA agar was pour aseptically into all sterilized, labelled petri- dish with each dilution factor. 0.1ml was pipetted out using a micropipette unto the petri-dish without fully opening the dish. The sterilized spreader was used to spread the inoculant of the agar, the dishes were turned upside down before incubating then at 37^oC for 24 hours. After which the colonies that appeared were counted using a colony counter. The result was then recorded.

3.10.4 Total Fungi and mold count

Sterile Petri-dishes were labeled by sample with each dilution factor. 0.1ml was pipetted out using a micropipette unto the petri-dish without fully opening the dish. The method of inoculation of the fungi and mold used was the pour plate method. The cooled PDA Agar was then poured aseptically into all petri-dish then shook gently. The dishes were left so the agar solidifies before incubating them at 37^oC for 2-5 day. After which the fungi growth were counted.

3.11 Sensory Evaluation

The sensory evaluation was carried out by 15 untrained panelists drawn from the final year students of Mountain Top University student who were familiar with the products. The sensory attributes evaluated include appearance, crust, texture, aroma, taste, mouth feel, and over acceptability for cake and doughnut; appearance, consistency texture, aroma, taste, mouth feel, and over acceptability for ice cream while the sausage appearance, texture, aroma, taste, mouth feel, and over acceptability was rated all on a 9- point hedonic scale, with 1 being the most disliked and 9 being the most liked (Omola, 2014). A special testing area was used for this evaluation so that distractions could be minimized and conditions could be controlled; the testing room should be

quiet, comfortable, with a consistent level of lighting and good ventilation; each panelist was given water to rinse their mouth after each evaluation. The samples were given codes before presented to the panelist, and an evaluation sheet was prepared for the panelists.

3.12 Statistical Analysis

Descriptive analysis was used in the statistical treatment of the data obtained in the experiment while T-test was used to establish differences among treatment using SPSS version 21. Significance was accepted at $p \leq 0.05$.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Properties of citrus waste dietary fiber

Phytochemical properties of citrus waste dietary fiber

The properties of citrus waste dietary fiber powder (mixture of segment wall and pith) is presented in Table 4.1. Most of the phytochemical properties determined were found to be more in sample B than in sample A. Samples A had (0.05 mg/cm^3, 0.47 mg/g, 0.01%, 1.27 mg/g, 0.33 mg/cm^3, and 1.60%) for phenol, flavonoid, phytate, oxalate, tannis, and alkaloids respectively while samples B had (0.07 mg/cm^3, 0.16 mg/g, 0.99%, 0.28 mg/cm^3, and 2.41% for phenols, phytate, oxalates, tannis and alkaloids. Although phenols, flavonoids and phytates have low values, their presence in citrus waste dietary fiber contributes to the antioxidant properties of the dietary fiber. While the low values for oxalates, tannis, and alkaloids will of advantage in preventing them from acting as anti-nutrients in the products. That is, they will not be able to chelate the nutrient present in the fortified products. This observation agreed with the findings of Adewole *et al.* (2014).

Soluble and insoluble dietary fiber (SDF and IDF) constituents of citrus waste dietary fiber

The soluble and insoluble dietary fiber (SDF and IDF) constituents of the mixed citrus wastes is also presented in Table 4.1. Sample A had 4.59% and 8.74%; while sample B had 5.38% and 10.16% for SDF and IDF, respectively. This shows that the dietary fiber produced from citrus wastes is acceptable for food ingredients as it meets the standard proportion of ratio 1:2 for SDF: IDF (Jaime et al., 2002). However, the mixed citrus dietary fiber sample B was discontinued for further experiments due to impactation of so much bitter taste to the fortified “junk” food products during the preliminary evaluation.

Table 4.1: Properties of citrus waste fiber powder

Phytochemical properties						
Sample	Phenols (mg/cm^3)	Flavonoids (mg/g)	Phytates (%)	Oxalates (mg/g)	Tannis (mg/cm^3)	Alkaloids (%)
A	0.05 ± 0.01^a	0.47 ± 0.01^a	0.01 ± 0.00^b	1.27 ± 0.01^a	0.33 ± 0.01^a	1.60 ± 0.01^b
B	0.07 ± 0.01^a	0.39 ± 0.01^b	0.16 ± 0.01^a	0.99 ± 0.00^b	0.28 ± 0.01^a	2.41 ± 0.01^a

Soluble and insoluble dietary fibre constituent		
Sample	SDF (%)	IDF (%)
A	4.59±0.02	8.74±0.02
B	5.38±0.04	10.16±0.02

Antioxidant activities		
Sample	DPPH (%)	FRAP (mg/g)
A	42.37±0.54	1.66±0.03

Functional properties					
Sample	WAI (g/ml)	OAI (g/ml)	LBD (g/ml)	PBD (g/ml)	Dispersibility (%)
A	3.97±0.02	1.02±0.01	0.45±0.01	0.67±0.01	8.67±5.77

Values are means of triplicates determinations±standard deviation; means with different superscript within the same column are significantly different ($p< 0.05$)

A = Mixture of segment wall (inner fibre); B = Mixture of pith (whitish spongy part); SDF = Soluble dietary fibre; IDF = Insoluble dietary fibre; DPPH =; FRAP =; WAI = Water absorption index; OAI = Oil absorption index; LBD = Loose bulk density; PBD = Packed bulk density

Antioxidant activity of citrus waste dietary fiber

The antioxidant activity of citrus waste dietary fiber (sample A) presented also in Table 4.1 showed that the DPPH and the FRAP had 42.37% and 1.66 mg/g, respectively This shows that the citrus wastes dietary fiber exhibits good antioxidant properties so that consumption of the fortified products could help mop up any free radicals in the body system.

Functional properties of the citrus wastes dietary fiber

Table 4.1 also show the result for functional properties of the citrus wastes dietary fiber (sample A). The water absorption index (WAI) determines the amount of water the flour will absorb during dough formation in bakery products. The obtained WAI (3.97 g/ml) for the citrus wastes dietary fiber will support a dough formation. The oil absorption index (OAI) is a measure of the oil that will be absorbed by the flour when mixing. It is an important functional attribute that enhances mouth feel while conserving food taste (Adebowale & Lawal, 2004). The obtained OAI (1.02 g/ml) for citrus wastes dietary fiber will be good enough to support good oil absorbance during mixing of bakery ingredient as well as impacting good mouth feel for the fortified "junk" food products. The obtained loose and packed bulk densities for the citrus waste dietary fiber 'A' are 0.45 g/ml and 0.67 g/ml, respectively, while the dispersability of citrus wastes dietary fiber is 8.67%. Bulk density is usually affected by the particle size and density of the flour and it is very important in determining the packaging requirement, materials handling and application in food preparation (Wang et al., 2009). The low value obtained for the bulk densities with prevent the heaviness of the fortified baked product.

4.2 Proximate composition of 'junk' food products with and without fiber fortification

The result obtained for the proximate analyses of different "junk" foods is presented in Table 4.12. The table shows that there was significant difference ($p \leq 0.05$) in the moisture content of the fortified "junk" foods and the unfortified "junk" foods. The fortified 'junk' foods had moisture content 20.66, 19.62, 60.83, and 54.00% for cake, doughnut, ice-cream, and sausage, respectively that were lower than those of the control samples 23.47%, 20.93%, 63.99%, and 57.50%. This could be due to increased total solid content as a result of the inclusion of citrus waste powder, which may support the shelf life of the fortified products. The low moisture content will improve the shelf life. On the other hands, the crude fiber contents of the fortified "junk" foods 0.66%, 1.04%, 1.14% and 0.68% were higher than those of the corresponding control samples 0.08%, 0.29%, 0.32% and 0.61%. This might be as a result of the inclusion of dietary fiber from citrus waste, which raised the fibre content of the fortified junk food and improve the products' nutritional value and subsequent health benefits.

The values obtained for the crude fat content of the fortified 'junk" foods in Table 4.2 are 24.15%, 36.95%, 8.75%, 14.95% for cake, doughnut, ice-cream, and sausage, respectively that were lower than those of the respective control samples are 23.03%, 32.15%, 7.82%,11.70%. This could be as a result of the dietary fiber replacement of wheat flour and fat in fortified "junk" foods and this could also help in preventing disease that may arise in the consumption of junk food with high fat and caloric index. This result can be backed up with the findings of (Haque et al., 2015). The ash values for fortified "junk" foods are 1.13%, 0.38%,0.93, 1.65% for cake, doughnut, ice-cream and sausage, and "junk" food without fortification values are 1.15%, 0.10%, 0.23%, 1.45% for cake, doughnut, ice-cream and sausage.

Table 4.2: Proximate composition of 'junk' food products with and without fiber fortification

Product	Moisture Content (%)	Ash (%)	Protein (%)	Crude Fiber (%)	Crude Fat (%)	Carbohydrate (%)
Cake						
ZF	20.66±0.43^{b}	1.13±0.13^{b}	7.92±0.04^{a}	0.66±0.07^{a}	24.15±4.20^{a}	45.48±4.78^{a}
ZN	23.47±0.21^{a}	1.15±0.00^{a}	7.83±0.04^{b}	0.08±0.08^{b}	23.03±1.28^{b}	44.44±0.95^{b}
Doughnut						
YF	19.62±0.01^{b}	0.38±0.28^{a}	9.72±0.26^{b}	1.04±0.04^{a}	36.95±2.55^{a}	32.30±2.04^{b}
YN	20.93±0.14^{a}	0.10±0.00^{b}	9.89±0.09^{a}	0.29±0.13^{b}	32.15±6.75^{b}	36.64±6.85^{a}
Ice-cream						
XF	60.83±0.35^{b}	0.93±0.20^{a}	4.51±0.04^{a}	1.14±0.14^{a}	8.75±0.15^{a}	23.85±0.58^{a}
XN	63.99±0.19^{a}	0.23±0.20^{b}	4.42±0.22^{a}	0.32±0.22^{b}	7.82±0.01^{a}	23.23±0.45^{a}
Sausage						
WF	54.00±1.65^{b}	1.65±0.55^{a}	11.59±0.13^{b}	0.68±0.13^{a}	14.95±0.60^{a}	11.17±5.26^{b}
WN	57.50±0.50^{a}	1.45±0.15^{b}	16.20±2.98^{a}	0.61±0.07^{b}	11.70±2.05^{b}	12.54±5.31^{a}

Values are means of triplicates determinations ± standard deviation; means with different superscript within the same column are significantly different ($p < 0.05$)

ZF = Cake with inclusion of citrus waste fibre; ZN = Cake with no inclusion of citrus waste fibre; YF = Doughnut with inclusion of citrus waste fibre; YN = Doughnut with no inclusion of citrus waste fibre; XF = Ice-cream with inclusion of citrus waste fibre; XN = Ice-cream with no inclusion of citrus waste fibre; WF = Sausage with inclusion of citrus waste fibre; WN = Sausage with no inclusion of citrus waste fibre

The protein values range from 4.42- 16.20% and were significant difference ($p \leq 0.05$) among the product while carbohydrate range from 11.17% - 45.48% and were also significantly difference ($p \leq 0.05$).

4.3 Colour evaluation on "junk" food product with and without fiber fortification

L, a, and b was determined using a colorimeter. It assessed the following colour traits: L (lightness) axis -0 is black, while 100 is white; a (red-green) axis- positive values are red, while negative values are green and 0 is neutral; b (yellow-blue) axis- positive values are yellow, while negative are blue are blue and 0 is neutral. According to the Table 4.3 XF and XN are significantly different p (<0.05), L values for XF and XN are 74.18 and 66.67 respectively. The degree of whiteness on XF is higher that of XN. a values for XF and XN are -0.83 and -0.49 respectively. Meaning a value for both XF and XN are negative value which is green. b value for XF and XN is 11.49 and 8.07 respectively meaning the degree of yellow is higher in that of XF probably because of the citrus fiber added to the ice cream. Also, in table 4.3 the degree of whiteness in ZF higher than that ZN. The degree of redness in ZF is also higher than that of ZN, the degree of yellowness in ZF is higher than that of ZN. There are significantly different from each other ($p<0.05$). The degree of whiteness in YN is higher than that of YF probably because of the addition of citrus fiber in YF. The degree of redness of YF is higher that of YN. The degree of yellowness in YN is higher than that of YF. The values are significantly difference to each other ($p \leq 0.05$). According to table 4.3in L and a, WN values are higher than WF and this is because of the addition of citrus fiber to the sausage. The ($p<0.05$).

Table 4.3: Colour analysis on 'junk' food products with and without fiber fortification

Product	L	a	b
Cake			
ZF	56.39±0.28[a]	3.73±0.02[a]	22.86±0.14[a]
ZN	54.62±0.22[b]	2.96±0.03[b]	22.64±0.09[b]
Doughnut			
YF	50.78±0.41[b]	6.67±0.10[a]	19.86±0.19[b]
YN	59.62±1.60[a]	4.58±0.36[b]	20.24±0.59[a]
Ice-cream			
XF	74.18±0.65[a]	-0.83±0.02[b]	11.49±0.20[a]
XN	66.67±0.47[b]	-0.49±0.01[a]	8.07±0.20[b]
Sausage			
WF	45.98±1.11[b]	2.66±0.04[b]	7.77±0.17[a]
WN	49.16±1.64[a]	2.92±0.39[a]	5.83±0.79[b]

Values are means of triplicates determinations ± standard deviation; means with different superscript within the same column are significantly different ($p < 0.05$)

L = L (lightness) axis -0 is black, while 100 is white; a =(red-green) axis- positive values are red, while negative values are green, and 0 is neutral; b = (yellow-blue) axis-positive values are yellow, negative values are blue, and 0 is neutral

ZF = Cake with inclusion of citrus waste fibre; ZN = Cake with no inclusion of citrus waste fibre; YF = Doughnut with inclusion of citrus waste fibre; YN = Doughnut with no inclusion of citrus waste fibre; XF = Ice-cream with inclusion of citrus waste fibre; XN = Ice-cream with no inclusion of citrus waste fibre; WF = Sausage with inclusion of citrus waste fibre; WN = Sausage with no inclusion of citrus waste fibre

4.4 Total viable bacteria count 'junk' food products with and without fiber fortification

The amount of Total Viable Bacteria Count (TVBC) was presented in Table 4.4. The values ranged between (7.0×10^{1} to 1.2×10^{4} CFU/ml). This values attained are from 10^{-1} to 10^{-3} diluent. The highest count was found in ice cream with fiber fortification (1.2×10^{4} CFU/ml) from 10^{-3} diluent. In MacConkey agar plates and Eosin Methylene Blue agar plate there were no significant growth on the plates which made the food safe for consumption.

4.5 Total viable fungi count 'junk food' product with and without fiber fortification

The amount of total viable fungi counts is presented in Table 4.5. The count ranged between (2.0×10^{1} to 2.0×10^{3} CFU/ml). This values attained are from 10^{-1} to 10^{-3} diluent with the highest count observed in ice cream with fiber fortification (2.0×10^{3} CFU/ml) from 10^{-3} diluent.

4.6 Sensory evaluation of 'junk' food products with and without fiber fortification

Sensory evaluation of "junk' food products with and without fiber fortification (Table 4.6). The overall acceptability of "junk" food product with and without fiber fortification range is from like moderately to like very much. The products were well acceptable by the panelists' ratings. The significant difference of "junk" food with and without fiber fortification is not pronounced. For cake with and without fiber fortification the values ranged from 7.67-7.80 for appearance, 7.73 – 7.80 for crust, 8.47 – 8.60 for aroma, 8.00 – 8.13 for texture, 7.73 – 8.47 for taste, 7.40 – 8.40 for mouth feel, 8.27 – 8.33 for overall acceptability. Doughnut with and without fiber fortification values ranged from 7.33 – 8.13 for appearance, 7.00 - 7.13 for crust, 7.27 – 7.47 for aroma, 6.93 – 7.20 for texture, 6.47 – 6.47 for taste, 6.87 for mouth feel and 7.47 – 7.60 for over acceptability. For ice-cream with and without fiber fortification values ranged 7.93 – 8.13 for appearance, 8.00 – 8.27 for aroma, 8.07 – 8.27 for texture, 8.20 for consistency, 8.20 for taste, 8.07 – 8.27 for mouth feel, 8.20 – 8.33 for overall acceptability. For sausage with and without fiber fortification values ranged from 7.47 – 7.67 for appearance, 7.67-7.87 for aroma, 7.20 – 7.33 for texture, 7.53 – 7.60 for taste, 7.27 – 7.40 for mouthfeel, 7.80 for overall acceptability.

Table 4.4: Total viable bacteria count 'junk' food products with and without fiber fortification

Sample	Colony forming units/serial dilution								
	Total viable bacterial counts on nutrient agar plates			MacConkey agar plates			Eosin Methylene Blue Agar plates		
	At 10^{-1} (cfu/mL)	At 10^{-2} (cfu/mL)	At 10^{-3} (cfu/mL)	At 10^{-1} (cfu/mL)	At 10^{-2} (cfu/mL)	At 10^{-3} (cfu/mL)	At 10^{-1} (cfu/mL)	At 10^{-2} (cfu/mL)	At 10^{-3} (cfu/mL)
ZF	7.0×10^{1}	NG	NG	NG	NG	NG	NG	NG	NG
ZN	1.6×10^{2}	NG	NG	NG	NG	NG	NG	NG	NG
YF	2.1×10^{2}	1.8×10^{3}	1.0×10^{4}	NG	NG	NG	NG	NG	NG
YN	1.2×10^{2}	NG	NG	NG	NG	NG	NG	NG	NG
XF	3.1×10^{2}	2.0×10^{3}	1.2×10^{4}	1.0×10^{2}	6.0×10^{2}	2.0×10^{3}	6.0×10^{1}	2.0×10^{2}	NG
XN	9.0×10^{1}	4.0×10^{2}	1.0×10^{4}	NG	NG	NG	NG	NG	NG
WF	1.7×10^{2}	3.0×10^{2}	NG	NG	NG	NG	NG	NG	NG
WN	4.4×10^{2}	3.6×10^{3}	NG	NG	NG	NG	NG	NG	NG

ZF = Cake with inclusion of citrus waste fibre; ZN = Cake with no inclusion of citrus waste fibre; YF = Doughnut with inclusion of citrus waste fibre; YN = Doughnut with no inclusion of citrus waste fibre; XF = Ice-cream with inclusion of citrus waste fibre; XN = Ice-cream with no inclusion of citrus waste fibre; WF = Sausage with inclusion of citrus waste fibre; WN = Sausage with no inclusion of citrus waste fibre ; NG = No growth

Table 4.5: Total viable fungi count of "junk" food products with and without fiber fortification

Sample	Colony forming units/serial dilution		
	Total Viable Fungi Count		
	At 10^{-1} (cfu/mL)	**At 10^{-2} (cfu/mL)**	**At 10^{-3} (cfu/mL)**
ZF	2.0×10^{1}	NG	NG
ZN	4.0×10^{1}	3.0×10^{2}	2.0×10^{3}
YF	NG	NG	NG
YN	5.0×10^{1}	3.0×10^{2}	1.0×10^{3}
XF	1.0×10^{2}	6.0×10^{2}	2.0×10^{3}
XN	NG	NG	NG
WF	NG	NG	NG
WN	NG	NG	NG

ZF = Cake with inclusion of citrus waste fibre; ZN = Cake with no inclusion of citrus waste fibre; YF = Doughnut with inclusion of citrus waste fibre; YN = Doughnut with no inclusion of citrus waste fibre; XF = Ice-cream with inclusion of citrus waste fibre; XN = Ice-cream with no inclusion of citrus waste fibre; WF = Sausage with inclusion of citrus waste fibre; WN = Sausage with no inclusion of citrus waste fibre; NG = No growth

Table 4.6: Sensory evaluation of 'junk' food products with and without fiber fortification

Product	Appearance	Crust	Aroma	Texture	Taste	Mouth feel	Overall acceptability
Cake							
ZF	7.67±1.29^{b}	7.80±0.94^{a}	8.47±0.74^{b}	8.00±1.36^{b}	7.73±1.22^{b}	7.40±1.40^{b}	8.27±0.88^{a}
ZN	7.80±1.15^{a}	7.73±0.88^{b}	8.60±0.83^{a}	8.13±0.99^{a}	8.47±0.74^{a}	8.40±0.74^{a}	8.33±0.82^{a}
Doughnut							
YF	7.33±1.35^{b}	7.13±1.46^{a}	7.47±1.13^{a}	7.20±1.26^{a}	6.47±1.36^{b}	6.87±1.46$_{a}$	7.60±0.91^{a}
YN	8.13±0.64^{a}	7.00±1.85^{b}	7.27±1.49^{b}	6.93±1.75^{b}	6.73+1.49^{a}	6.87±1.64^{a}	7.47±1.41^{b}

Product	Appearance	Aroma	Texture	Consistency	Taste	Mouth feel	Overall acceptability
Ice-cream							
XF	8.13±1.36^{a}	8.27±0.80^{a}	8.27±0.88^{a}	8.20±1.15^{a}	8.20±0.86^{a}	8.07±0.96^{b}	8.33±0.82^{a}
XN	7.93±1.33^{b}	8.00±1.13^{b}	8.07±1.03^{b}	8.20±0.94^{a}	8.20±1.15^{a}	8.27±0.80^{a}	8.20±0.94^{b}

Product	Appearance	Aroma	Texture	Taste	Mouth feel	Overall acceptability
Sausage						
WF	7.47±1.36^{b}	7.67±1.23^{b}	7.20±1.32^{a}	7.53±1.41^{a}	7.27±1.75^{b}	7.80±1.15^{a}
WN	7.67±1.18^{a}	7.87±1.13^{a}	7.33±1.50^{a}	7.60±1.18^{a}	7.40±1.24^{a}	7.80±1.37^{a}

Values are means of triplicates determinations ± standard deviation; means with different superscript within the same column are significantly different ($p < 0.05$)

ZF = Cake with inclusion of citrus waste fibre; ZN = Cake with no inclusion of citrus waste fibre; YF = Doughnut with inclusion of citrus waste fibre; YN = Doughnut with no inclusion of citrus waste fibre; XF = Ice-cream with inclusion of citrus waste fibre; XN = Ice-cream with no inclusion of citrus waste fibre; WF = Sausage with inclusion of citrus waste fibre; WN = Sausage with no inclusion of citrus waste fibre

CHAPTER FIVE

5.0 Conclusion and Recommendation

5.1 Conclusion

The results of this work has shown that the produced dietary fiber powder from the citrus fruit wastes meets the standard of being used as food ingredient in terms of the insoluble and soluble dietary fibre constituents and the application in fortification of "junk" foods proved to be effective in improving the nutritive value especially the dietary fibre content. Hence, the rate of human health defect through the habitual consumption of "junk" foods could then be reduced. Additionally, finding a useful application for citrus wastes dietary fiber will also minimise the environmental pollution that poor management of the wastes could generate and also improve the economic importance.

5.2 Recommendation

Higher percentages of the citrus waste dietary fiber inclusion that the ones used in the present work should be tried in "junk" food production. Additionally, in vivo experiment on rats could be performed to validate the improved nutritional and health benefits of citrus waste dietary fiber fortified "junk" foods.

REFERNCES

Adamo, K. B., & Brett, K. E. (2014). Parental perceptions and childhood dietary quality. *Maternal and child health journal*, 18(4), 978-995.

Adebowale, K. O., & Lawal, O. S. (2004). Comparative study of the functional properties of bambarra groundnut (Voandzeia subterranean), jack bean (Canavalia ensiformis) and mucuna bean (Mucuna pruriens) flours. *Food Research International*, 37, 355–365.

Adewole, E., Adewumi, D. F., Jonathan, J., & Fadaka, A. O. (2014). Phytochemical constituents and proximate analysis of orange peel (citrus Fruit). *Journal of advanced Botany and zoology*, 1(3), 1-2.

Afolabi, W. A. O., Oyawoye, O. O., Sanni, S. A., & Onabanjo, O. O. (2013). Proximate and cholesterol composition of selected fast foods sold in Nigeria. Nigerian Food Journal, 31(1), 70-76

Akpata, M. I., & Akubor, P. I. (1999). Chemical composition and selected functional properties of sweet orange (Citrus sinensis) seed flour. *Plant foods for human nutrition*, 54(4), 353-362.

Ali, A., & Mulla, M. S. (1976). Insecticidal control of chironomid midges in the Santa Ana river water spreading system, Orange County, California. *Journal of Economic Entomology*, 69(4), 509-513.

AOAC, Official Methods of Analysis, 19th edn. (Association of Offcial Analytical Chemist International, Rockville, 2012).

Arulogun O.A and Owolabi M.O., (2011) 'Fast Food Consumption Pattern among Undergraduates of the University of Ibadan, Nigeria: Implications for Nutrition Education J. Agric. Food. Tech., 1(6) 89-93

Arya, G., & Mishra, S. (2013). Effect of junk food & beverages on Adolescent's health. IOSR *Journal of nursing and health science*, 1, 26-32.

Braddock, R. J. (1999). Handbook of *citrus by-products processing technology*. John Wiley.

Bruni, R., Barreca, D., Protti, M., Brighenti, V., Righetti, L., Anceschi, L., ... & Pellati, F. (2019). Botanical sources, chemistry, analysis, and biological activity of furanocoumarins of pharmaceutical interest. *Molecules*, 24(11), 2163.

Carolyn, D. B., Johanna, T. D., & Elaine, B. F. (2007). *Handbook of Nutrition and Food* (Eds).

Carr, A. C., & Vissers, M. C. (2013). Synthetic or food-derived vitamin C—are they equally bioavailable?. *Nutrients*, 5(11), 4284-4304.

Carrington, J. C., & Ambros, V. (2003). Role of microRNAs in plant and animal development. *Science*, 301(5631), 336-338.

Champ, M., Langkilde, A. M., Brouns, F., Kettlitz, B., & Collet, Y. L. B. (2003). Advances in dietary fibre characterisation. 1. Definition of dietary fibre, physiological relevance, health benefits and analytical aspects. *Nutrition Research Reviews*, 16(1), 71-82.

Chau, C. F., Sheu, F., Huang, Y. L., & Su, L. H. (2005). Improvement in intestinal function and health by the peel fibre derived from Citrus sinensis L cv Liucheng. *Journal of the Science of Food and Agriculture*, 85(7), 1211-1216.

Chavan, P., Singh, A. K., & Kaur, G. (2018). Recent progress in the utilization of industrial waste and by-products of citrus fruits: A review. *Journal of Food Process Engineering*, 41(8), e12895.

Chavan, P., Singh, A. K., & Kaur, G. (2018). Recent progress in the utilization of industrial waste and by-products of citrus fruits: A review. Journal of Food Process Engineering, 41(8), e12895.

Cirmi, S., Bisignano, C., Mandalari, G., & Navarra, M. (2016). Anti-infective potential of Citrus bergamia Risso et Poiteau (bergamot) derivatives: a systematic review. *Phytotherapy Research*, 30(9), 1404-1411.

Cirmi, S., Maugeri, A., Ferlazzo, N., Gangemi, S., Calapai, G., Schumacher, U., & Navarra, M. (2017). Anticancer potential of citrus juices and their extracts: a systematic review of both preclinical and clinical studies. *Frontiers in Pharmacology*, 8, 420.

Dinu, M., Pagliai, G., & Sofi, F. (2017). A heart-healthy diet: recent insights and practical recommendations. *Current cardiology reports*, 19(10), 1-7.

Dinu, M., Whittaker, A., Pagliai, G., Benedettelli, S., & Sofi, F. (2018). Ancient wheat species and human health: Biochemical and clinical implications. *The Journal of nutritional biochemistry*, 52, 1-9.

Dosoky, N. S., & Setzer, W. N. (2018). Biological activities and safety of Citrus spp. essential oils. *International journal of molecular sciences*, 19(7), 1966.

Dumanovsky, T., Huang, C. Y., Nonas, C. A., Matte, T. D., Bassett, M. T., & Silver, L. D. (2011). Changes in energy content of lunchtime purchases from fast food restaurants after introduction of calorie labelling: cross sectional customer surveys. *Bmj*, *343*.

Elleuch, M., Bedigian, D., Roiseux, O., Besbes, S., Blecker, C., & Attia, H. (2011). Dietary fibre and fibre-rich by-products of food processing: Characterisation, technological functionality and commercial applications: A review. *Food chemistry*, 124(2), 411-421.

FAO. Citrus Fruit Fresh and Processed—Statistical Bulletin. Available online: http://www.fao.org/3/a-i8092e.pdf

Fatsecret Platform (2008). https://www.fatsecret.com.au/caloriesnutrition/generic/grapefruit?portionid=53938&por

tionamount=100.000 Accessed on 11 August, 2022.

Fernández-Ginés, J. M., Fernández-López, J., Sayas-Barberá, E., Sendra, E., & Perez-Alvarez, J. A. (2004). Lemon albedo as a new source of dietary fiber: Application to bologna sausages. *Meat science*, 67(1), 7-13.

Figuerola, F., Hurtado, M. L., Estévez, A. M., Chiffelle, I., & Asenjo, F. (2005). Fibre concentrates from apple pomace and citrus peel as potential fibre sources for food enrichment. *Food chemistry*, 91(3), 395-401.

Fuentes-Zaragoza, E., Riquelme-Navarrete, M. J., Sánchez-Zapata, E., & Pérez-Álvarez, J. A. (2010). Resistant starch as functional ingredient: A review. *Food Research International*, 43(4), 931-942.

Fuentes-Zaragoza, E., Sánchez-Zapata, E., Sendra, E., Sayas, E., Navarro, C., Fernández-López, J., & Pérez-Alvarez, J. A. (2011). Resistant starch as prebiotic: A review. *Starch-Stärke*, 63(7), 406-415.

Fuhrman, J. (2018). The hidden dangers of fast and processed food. *American journal of lifestyle medicine*, 12(5), 375-381.

Garcıa, M. L., Dominguez, R., Galvez, M. D., Casas, C., & Selgas, M. D. (2002). Utilization of cereal and fruit fibres in low fat dry fermented sausages. *Meat science*, 60(3), 227-236.

Gedikoğlu, A., & Clarke, A. D. (2019). Quality attributes of citrus fiber added ground beef and consumer acceptance of citrus fiber added Turkish meatballs. *Food and health*, 5(4), 205-214.

Godwin, S. (2020). Children's capacities and paternalism. *The Journal of Ethics*, 24(3), 307-331.

Gonnet, J. F. (1999). Colour effects of co-pigmentation of anthocyanins revisited—2. A colorimetric look at the solutions of cyanin co-pigmented byrutin using the CIELAB scale. *Food Chemistry*, 66(3), 387-394.

Gupta, A., Kapil, U., & Singh, G. (2018). Consumption of junk foods by school-aged children in rural Himachal Pradesh, India. *Indian journal of public health*, 62(1), 65.

Gupta, V., Bansal, P., Kohli, K., & Ghaiye, P. (2014). Development of economic herbal based drug substitute from Citrus paradisi (Grape fruit) for existing anti-anxiety drug modules. *Nat Prod Chem* Res S, 1, 2.

Haque, F., Rahman, M. H., Habib, M., Alam, M. S., Monir, M. M., & Hossain, M. M. (2020). Effect of different levels of orange peel extract on the quality and shelf life of beef muscle during frozen storage. IOSR J. Agric. Vet. Sci, 13, 43-56.

Harborne, J. B. (1973). Phenolic compounds. *In Phytochemical methods* (pp. 33-88). Springer, Dordrecht.

Hussain, S. Z., Naseer, B., Qadri, T., Fatima, T., & Bhat, T. A. (2021). Citrus fruits—Morphology, taxonomy, composition and health benefits. In *Fruits Grown in Highland Regions of the Himalayas* (pp. 229-244). Springer, Cham.

Jaime, L., Mollá, E., Fernández, A., Martín-Cabrejas, M. A., López-Andréu, F. J., & Esteban, R. M. (2002). Structural carbohydrate differences and potential source of dietary fiber of onion (Allium cepa L.) tissues. *Journal of Agricultural and Food Chemistry*, 50(1), 122-128.

Johnson, C. M., Sharkey, J. R., Dean, W. R., McIntosh, W. A., & Kubena, K. S. (2011). It's who I am and what we eat. Mothers' food-related identities in family food choice. *Appetite,* 57(1), 220-228.

Kaczmarczyk, A., Funnekotter, B., Menon, A., Phang, P. Y., Al-Hanbali, A., Bunn, E., & Mancera, R. (2012). Current issues in plant cryopreservation. In Current *frontiers in cryobiology* (pp. 417-438). InTech.

Kim, J. H., & Kim, M. Y. (2016). The potential use of citrus juice waste as sources of natural phenolic antioxidants. *Journal of Applied Pharmaceutical Science*, 6(12), 202-205.

Kinsella, J. E., & Melachouris, N. (1976). Functional properties of proteins in foods: a survey. *Critical Reviews in Food Science & Nutrition*, 7(3), 219-280.

Kumar, N., & Goel, N. (2019). Phenolic acids: Natural versatile molecules with promising therapeutic applications. *Biotechnology Reports*, 24, e00370.

Lee, S. C., Prosky, L., & Vries, J. W. D. (1992). Determination of total, soluble, and insoluble dietary fiber in foods—Enzymatic-gravimetric method, MES-TRIS buffer: Collaborative study. *Journal of AOAC international*, 75(3), 395-416.

Li, Q., Ning, P., Zheng, L., Huang, J., Li, G., & Hsiang, T. (2010). Fumigant activity of volatiles of Streptomyces globisporus JK-1 against Penicillium italicum on Citrus microcarpa. *Postharvest Biology and Technology*, 58(2), 157-165.

Mahato, N., Sharma, K., Sinha, M., & Cho, M. H. (2018). Citrus waste derived nutra-/pharmaceuticals for health benefits: Current trends and future perspectives. *Journal of Functional Foods, 40*, 307-316.

Mangan, R. L., Thomas, D. B., Tarshis Moreno, A., & Robacker, D. (2011). Grapefruit as a host for the West Indian fruit fly (Diptera: Tephritidae). *Journal of economic entomology*, *104*(1), 54-62.

Mensor, L. L., Menezes, F. S., Leitão, G. G., Reis, A. S., Santos, T. C. D., Coube, C. S., & Leitão, S. G. (2001). Screening of Brazilian plant extracts for antioxidant activity by the use of DPPH free radical method. *Phytotherapy research*, 15(2), 127-130.

Morton, J. (1987). Orange. *Fruits of warm climates*, 134-142.

Musumeci, L., Maugeri, A., Cirmi, S., Lombardo, G. E., Russo, C., Gangemi, S., ... & Navarra, M. (2020). Citrus fruits and their flavonoids in inflammatory bowel disease: *An overview. Natural product research*, 34(1), 122-136.

Nagano, Y., Mimura, T., Kotoda, N., Matsumoto, R., Nagano, A. J., Honjo, M. N., ... & Yamamoto, M. (2018). Phylogenetic relationships of Aurantioideae (Rutaceae) based on RAD-Seq. *Tree genetics & genomes*, 14(1), 1-11.

Omola, E. M., Kawo, A. H., & Shamsudden, U. (2014). Physico-chemical, sensory and microbiological qualities of yoghurt brands sold in Kano metropolis, Nigeria. Bayero Journal of pure and applied sciences, 7(2), 26-30.

O'neill, T., Jinks, C., & Squire, A. (2006). "Heating is more important than food" older women's perceptions of fuel poverty. *Journal of Housing for the Elderly*, 20(3), 95-108.

Osorio, L. L. D. R., Flórez-López, E., & Grande-Tovar, C. D. (2021). The potential of selected agri-food loss and waste to contribute to a circular economy: Applications in the food, cosmetic and pharmaceutical industries. *Molecules*, 26(2), 515.

Park, S., Lee, Y., & Lee, J. H. (2016). Association between energy drink intake, sleep, stress, and suicidality in Korean adolescents: energy drink use in isolation or in combination with junk food consumption. *Nutrition journal*, 15(1), 1-8.

Pulido, R., Bravo, L., & Saura-Calixto, F. (2000). Antioxidant activity of dietary polyphenols as determined by a modified ferric reducing/antioxidant power assay. *Journal of agricultural and food chemistry*, 48(8), 3396-3402.

Rafiq, S., Kaul, R., Sofi, S. A., Bashir, N., Nazir, F., & Nayik, G. A. (2018). Citrus peel as a source of functional ingredient: *A review. Journal of the Saudi Society of Agricultural Sciences, 17(4),* 351-358.

Rosa, A.; Era, B.; Masala, C.; Nieddu, M.; Scano, P.; Fais, A.; Porcedda, S.; Piras, A. Supercritical CO2 extraction of waste citrus seeds: Chemical composition, nutritional and biological properties of edible fixed oils. Eur. J. Lipid Sci. Technol. 2019, 121, 1800502.

Ruiz, B., & Flotats, X. (2014). Citrus essential oils and their influence on the anaerobic digestion process: An overview. *Waste management*, *34*(11), 2063-2079.

Sauberlich, H. E., Packer, L., & Fuchs, J. (1997). A history of scurvy and vitamin C. ANTIOXIDANTS IN HEALTH AND DISEASE SERIES, 1-24.

Scott, C. (2018). Sustainably sourced junk food? Big food and the challenge of sustainable diets. *Global Environmental Politics*, 18(2), 93-113.

Searcey, D., & Richtel, M. (2017). Obesity was rising as Ghana embraced fast food. Then came KFC. *The New York Times*, 2.

Sharma, K., Mahato, N., Cho, M. H., & Lee, Y. R. (2017). Converting citrus wastes into value-added products: Economic and environmently friendly approaches. *Nutrition,* 34,29-46.

Sharoba, A. M., Farrag, M. A., & El-Salam, A. (2013). Utilization of some fruits and vegetables wastes as a source of dietary fibers in cake making. *Journal of Food and Dairy Sciences*, 4(9), 433-453.

Siles, J. A., Vargas, F., Gutiérrez, M. C., Chica, A. F., & Martín, M. A. (2016). Integral valorisation of waste orange peel using combustion, biomethanisation and co-composting technologies. *Bioresource* Technology, 211, 173-182.

Song, Y. (2016). Factors that affect fast food consumption: A review of the literature. MBA Student Scholarship.

Surya, V., Arul, M., & Arockiaraj, A. (2020). Junk Food is the Danger of Future Generation–Review for a Decade. *EXECUTIVE EDITOR*, 11(6), 1160.

Taghizadeh-Alisaraei, A., Hosseini, S. H., Ghobadian, B., & Motevali, A. (2017). Biofuel production from citrus wastes: A feasibility study in Iran. *Renewable and Sustainable Energy Reviews,* 69, 1100-1112.

Talón, M., Wu, G. A., Gmitter Jr, F. G., & Rokhsar, D. S. (2020). The origin of citrus. In *The genus citrus* (pp. 9-31). Woodhead Publishing.

Terpstra, A. H. M., Lapre, J. A., De Vries, H. T., & Beynen, A. C. (2002). The hypocholesterolemic effect of lemon peels, lemon pectin, and the waste stream material of lemon peels in hybrid F1B hamsters. *European journal of nutrition*, 41(1), 19-26.

Tomar, A., Mall, M., & Rai, P. (2013). Pharmacological importance of citrus fruits. *International journal of pharmaceutical sciences and research*, *4*(1), 156.

Umaru, H. A., Adamu, R., Dahiru, D., & Nadro, M. S. (2007). Levels of antinutritional factors in some wild edible fruits of Northern Nigeria. *African Journal of Biotechnology*, 6(16).

Velasco, R., & Licciardello, C. (2014). A genealogy of the citrus family. *Nature biotechnology*, 32(7), 640-642.

Wheeler, E. L., & Ferrel, R. E. (1971). A method for phytic acid determination in wheat and wheat fractions. *Cereal chemistry*, 48(3), 312-320.

Widjaja-Adhi, M.A.K.; Ramkumar, S.; von Lintig, J. Protective role of carotenoids in the visual cycle. FASEB J. Off. Publ. Fed. Am. Soc. aoExp. Biol. 2018, 32, 6305–6315.

Wiles, N. J., Northstone, K., Emmett, P., & Lewis, G. (2009). 'Junk food'diet and childhood behavioural problems: results from the ALSPAC cohort. *European journal of clinical nutrition*, 63(4), 491-498.

Xu, Q., Chen, L. L., Ruan, X., Chen, D., Zhu, A., Chen, C., ... & Ruan, Y. (2013). The draft genome of sweet orange (Citrus sinensis). Nature genetics, 45(1), 59-66.

Zema, D. A., Calabrò, P. S., Folino, A., Tamburino, V. I. N. C. E. N. Z. O., Zappia, G., & Zimbone, S. M. (2018). Valorisation of citrus processing waste: A review. *Waste management*, 80, 252-273.

APPENDIX

Scoring sheet for sensory analysis

DATE: ……

SEX: ……

AGE (Tick): 18-30 ( ); 30-45( ); 45-60( )

You are provided with **8 different samples coded accordingly**. You are required to score each sample based on your preference using the scale provided below.

Scale: 9= Like extremely, **8**= Like very much, **7**= Like moderately, **6**= Like slightly, **5**= Neither like or dislike, **4**= Dislike slightly, **3**= Dislike moderately, **2**= Dislike very much, **1**= Dislike extremely.

SECTION A (SAMPLE Z)

Sample	Appearance	Crust	Aroma	Texture	Taste	Mouthfeel	Aftertaste	Overall acceptability
ZF								
ZN								

SECTION B (SAMPLE Y)

Sample	Appearance	Crust	Aroma	Texture	Taste	Mouthfeel	Aftertaste	Overall acceptability
YF								
YN								

SECTION C (SAMPLE X)

Sample	Appearance	Aroma	Texture	Consistency	Mouthfeel	Taste	Aftertaste	Overall Acceptability
XF								
XN								

SECTION D (SAMPLE W)

Sample	Appearance	Aroma	Texture	Taste	Mouthfeel	Aftertaste	Overall Acceptability
WF							
WN							