

Nutritive Assessment & Acceptability of Bread Fortified with Avocado Seed Powder

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Certification

This is to certify that **Ololade Zainab VIAVONU** with matriculation number **LCU/PG/005076** carried out this research work titled “**Nutritive Assessment and Acceptability of Bread Fortified with Avocado Seed Powder**” in the Department Human Nutrition and Dietetics, Faculty of Basic Medical and Applied Sciences of Lead City University Ibadan, Oyo State, for the award of Master of Science Degree [MSc] in Human Nutrition and Dietetics.

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Dedication

This research work is dedicated to God Almighty for seeing me through.

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Acknowledgement

I sincerely express my gratitude to Lead City University, Ibadan, Oyo State, Nigeria for the training, coaching and knowledge the institution has passed to me. It is indeed a citadel of knowledge for self-reliance. My sincere gratitude also goes to the Librarian at Lead City University of Ibadan for providing a rich source of information for a research of this magnitude.

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Although the aforementioned institution and individuals have provided support throughout the course of this research endeavor, I bear sole accountability for any inaccuracies, if present, identified within the work.

Abstract

This research assesses the efficacy of avocado seed powder (ASP) in the fortification of bread. The incorporation of avocado seed powder into bread formulations occurred at 5% and 10% of the weight of flour, alongside fixed ratios of other ingredients (yeast, butter, milk, egg, sugar and water). The fortified dough underwent evaluation for proximate composition, antioxidant activity, and functional properties utilizing standardized chemical methodologies. Furthermore, a sensory evaluation involving 30 participants was performed employing a hedonic scale. Findings indicated that the fortification of bread with ASP significantly elevated its fiber content ($P < 0.05$), concurrently leading to a reduction in protein and fat content ($P < 0.05$) as the levels of ASP increased. The total phenolic content varied from 0.39 ng/kg in the control bread to 2.10 ng/kg in the bread containing 10% ASP. Additionally, avocado seed powder enhanced the antioxidant capacity of the bread, with Diphenyl-2-picryl-hydrazyl (DPPH) radical scavenging activity increasing from 57.83% in control samples to 62.41% in bread comprising 5% ASP. Functional attributes such as bulk density and water absorption capacity were markedly improved with the incorporation of ASP. Sensory evaluation showed that the inclusion of ASP adversely influenced the appearance of the bread but did not significantly affect flavor or overall acceptability ($P > 0.05$). The study concludes that the addition of avocado seed powder, at levels up to 10%, enhances the nutritional profile of bread without substantially compromising consumer acceptability.

Keywords: Avocado seed powder, Nutritive Assessment, Fortification, Acceptability.

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List of Acronyms

Abbreviation	Meaning
LBD	Loose Bulk Density
OAC	Oil Absorption Capacity
FS	Foam Stability
EC	Emulsion Capacity
ASP	Avocado Seed Powder
LGC	Least Gelation Capacity
SC	Swelling Capacity
PBD	Packed Bulk Density
FC	Foaming Capacity
WAC	Water Absorption Capacity
SEM	Standard Error of Mean
WHO	World Health Organization
NCD	Non- Communicable Disease
GHG	Greenhouse Emission
MUFA	Monosaturated Fatty Acid
FDA	Food and Drug Administration
IDF	International Diabetes Federation
OA	Osteoarthritis
TBARS	Thiobarbiturate Reactive Species
SNP	Sodium Nitroprusside
FW	Food Waste

UV

Ultraviolet

BMI

Body Mass Index

PUFA

Polysaturated Fatty Acids

AD

Alzheimer's disease

PARP

Poly-ADP ribose polymerase

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Chapter One

Introduction

1.1 Background of the Study

Noncommunicable diseases are the leading burdens causing mortality and morbidity rates globally, having high impacts on wealthy and poor countries. The conditions include chronic respiratory disorders, diabetes mellitus, obesity, malignancies, cardiovascular diseases, and cognitive dysfunction ¹. Although genetic and environmental determinants are known risk factors, lifestyle-related variables amenable to modification are much more important at an individual level ^{2,3,4}. For instance, dietary choices may enhance the risk of incidence of inflammation, hypertension, hypercholesterolemia, overweight/obesity, and other states that predispose diseases such as cancers, diabetes, and cardiovascular diseases associated with high morbidity and mortality ⁵. In fact, the rapid upsurge in chronic NCDs is indeed causally related to more Westernized global dietary patterns typical of low intakes of fresh fruits and vegetables, and high intakes of processed and fatty meats, saturated fats, refined carbohydrates, salt, and sweets. The dietary habits are identified by the World Health Organization Global Action Plan for the Prevention and Control of Noncommunicable Diseases as a modifiable lifestyle factor contributing to the pattern of disease. Diet, therefore, forms part of its actions to reduce behavioral risk factors through the promotion of unhealthy diet patterns ⁶. Added risk factors are physical inactivity, tobacco use, and hazardous alcohol consumption ¹. Recommendations include the adjustment of diet; balance in energy intake, increased unsaturated fats consumption and reduction in saturated and Tran's fats. Fruit and vegetable consumption is to be increased and

reduced sugar and salt use. Specific regional diets such as the Mediterranean diet do carry different nutritional goals inherently with them ⁷. Antioxidants are a component of evidence-based diets like the Dietary Approaches to Stop Hypertension (DASH) that lower the risk of disease, Additionally, Mediterranean Diets for Neurodegenerative Delay Intervention (MIND) ^{8,9}. This narrative review delineates the attributes and corroborating clinical and epidemiological evidence for diets adhering to the guidelines set forth by the World Health Organisation (WHO) which have been shown to prevent disease and /or improve health in order to better comprehend the current concept of a healthy diet ⁹.

Analysis for the studies typically entails the nutritional makeup of the fortified bread compared to the conventional one by assessing some key parameters, including among others: protein, fiber, vitamins, and minerals. Sensory analysis of this study will also ascertain the acceptability of the fortified bread through taste tests and consumer surveys, assessing its texture, flavor, aroma, and overall acceptability to appeal to the preference of the consumers.

Generally, this study will determine whether avocado seed powder can be one of the potential ingredients in bread production since it will improve nutritional value without affecting taste and consumer satisfaction.

1.2 Statement of the Problem

Improving nutritonal value of bread. Avocado seeds contain several numbers of phytochemicals, nutrients and each of them plays a beneficial role in preventing diseases. Avocado seeds are rich in antioxidants, fiber and other beneficial compounds that could enhance the nutritional value of foods consumed³. This seeks to explore both the nutritional impact and consumer reception of this innovative food product.

1.3 Justifications of the Study

Antioxidants, which give fruits their vibrant color and work as scavengers, cleaning up free radicals before they create harmful health consequences, are currently attracting a lot of attention. Several studies have emphasized cardiovascular disease risk by increasing potential of fruits

1.4 Aim and Objectives of the Study

Broad Objectives

The aim of the research work is to assess the efficacy of the avocado seed powder in bread fortification.

Specific Objectives are to:

- i. Determine the nutritive components and antioxidant status of avocado seed powder.
- ii. Evaluate the functional properties of avocado seed powder.
- iii. Determine the nutritive value and functional properties of bread fortified with avocado seed powder
- iv. Asses the antioxidant status and consumer acceptability of bread fortified with avocado seed powder.

1.5 Research Questions

- i. How to determine nutritive components and antioxidant status of avocado seed powder
- ii. How to evaluate the functional properties of avocado seed powder
- iii. In what ways are nutritive value and functional properties of bread fortified with avocado seed powder determined.

1.6 Significant of the Study

It lies in its potential benefits for nutritional, health, sustainability and food innovation.

This research is valuable for the following reasons;

Bread enriched with fiber, antioxidants, and minerals from avocado seeds could provide added health benefits, especially for consumers seeking healthier dietary options. Further innovation in the use of underutilized plant by-products, potentially creating new opportunities and economic benefits for food producers.

1.7 Scope of the Study

The element being analyzed to determine the fortifications impact on the bread's overall nutritional profile, the acceptability based on sensory characteristics like taste, texture, color and aroma at different concentrations of avocado seed powder at 0%, 5% and 10%.

1.8 Limitations of the Study

This include sourcing, processing and incorporating avocado seed powder into bread may increase production costs, affecting economic viability. Shelf-life and storage concerns of the bread.

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Chapter Two

Literature Review

2.1 Conceptual Review on Avocado

A diverse array of avocados belongs to the Lauraceae family, particularly the *Persea Americana* species. The avocado tree is classified as deciduous and can be propagated via grafting techniques or through seedlings. An adult tree has the potential to reach a height of 18–20 meters (66 feet), exhibiting a trunk diameter ranging from 30 to 60 cm. Depending on the type, the size and shape of the leaves vary in their alternating arrangement. They are typically hairy while they are young and turn smooth and leathery as they get older. Every tree has the capacity to yield hundreds of flawless blooms, of which only around 5% normally become fertilized and bear avocado fruits. Nevertheless, it is possible for the trees to develop but not bear fruit if the surrounding conditions are unfavorable ¹. The harvesting times of the many avocado cultivars typically fluctuate greatly, and there is also a large temporal fluctuation (ranging from 4 to 10 months) between the flowering moment and the fruit maturing and harvest. Young plants require special attention and defense against intense sunlight and wind. They typically begin to reproduce when they are four to five years old. But it takes another four to five years for them to reach their full production potential. Intercropping, or the cultivation of a variety of fruit-bearing trees, such as mangoes, citrus species, palm trees, and even olive varieties, within the same agricultural plot is a widely embraced methodology. The avocado tree serves as a pertinent illustration of this concept; it necessitates a temperate climate accompanied by a sufficient supply of water—either through precipitation or irrigation—in order to yield fruit, yet it is incapable of enduring excessively arid winds or frost conditions. Assume that the weather is pleasant and there is an adequate supply of water.

Then, avocados are a crop that is quite simple to manage and don't require a lot of fertilizer or crop protection. Organic farming is therefore a feasible and workable alternative. But avocado growers are finding it increasingly difficult to protect their crops against climate change, which is already evidently having a detrimental impact on productivity, the fruit can be shaped like a pear, egg, or sphere, depending on the variety. Its green skin can be smooth or speckled, and as it ripens, it can turn purple, dark brown, or even black. The flesh is pale green to yellow in hue and has a creamy texture. Two thin, papery, brown seed coverings surround a single, big seed in the center of the fruit ².

Fruits from contemporary varieties typically ranges in length from 7 to 20 cm ³, and it can weigh anywhere between 150 and 400–500g ³. Avocado ripens even after it has been harvested (removed from the tree) since it is a climacteric berry. To prevent harming the fruits, the farmer must use extreme caution when harvesting and storing them. The variety, temperature of the storage environment, and the degree of ripeness of the fruit at harvest all have a significant impact on shelf life and storage.

2.1.1 Health Benefits of Avocado

Avocado Components Related to Fatty Acids and Cardiovascular Health

Avocados can be integrated into dietary patterns that promote cardiovascular health, such as the DASH (Dietary Approaches to Stop Hypertension) dietary framework. ⁴. Avocados contain a lipid fraction characterized by a predominance of monounsaturated fatty acids (MUFA), comprising 71% of the total lipid content, with polyunsaturated fatty acids (PUFA) accounting for 13% and saturated fatty acids (SFA) constituting 16%. Saturated fat in avocado fruit reduces with ripening, but monounsaturated oleic acid increases ^{5, 6, 7}.

Reducing dietary SFA consumption can be improved by using avocado spreads and dips instead of more conventional hard, SFA-rich spreads or dips ⁸.

Carbohydrates Dietary Fibre

About 80% of the carbohydrates in avocado fruit are dietary fiber, with 70% of it being insoluble and 30% being soluble ⁹. For each 30 g of avocados and half of the fruit, the dietary fiber content is quantified at 2.0 g and 4.6 g, respectively. ¹⁰. As a result, taking half an avocado can provide approximately one-third of the recommended daily intake of 14 g of dietary fiber per 1000 calories, which can be achieved by moderate avocado consumption.

Sugars

Compared to other fruits, avocados contain a very little amount of sugar¹⁰. Just about 0.2 grams of sugar (such as sucrose, glucose, and fructose) are present in one-half of an avocado. D-mannoheptulose, a special seven-carbon sugar, is the main sugar found in avocados. Perseitol, a reduced form of this sugar, provides roughly 2.0 g for every half of an avocado, because it behaves differently from regular sugar in terms of nutrition and more like a special phytochemicals found in avocados, it is not included in the compositional database as sugar but it is not included in the compositional database as sugar ^{11,12}. D-mannoheptulose may help with weight management and blood glucose regulation, according to preliminary research ¹³. An avocado is predicted to have a glycemic index and load of roughly zero.

Minerals

Potassium

Clinical data indicates that individual's blood pressure regulation may be enhanced by consuming enough potassium ¹⁴. In the United States, adults consumed an average of 3200 mg of potassium daily for men and 2400 mg for a woman, which is less than the 4700 mg daily recommended intake ^{15, 16}. About 152 mg and 345 mg of potassium are included in each 30 g and half of an avocado, respectively. Furthermore, avocados have a comparatively low natural salt content –just 2 mg and 5.5 mg per 30 g and half of the fruit, respectively¹⁰. Foods containing 350 mg of potassium and less than 140 mg of sodium per serving are recognized as potentially pertinent for the blood pressure health assertion¹⁶.

Magnesium

Magnesium supports appropriate vascular tone and insulin sensitivity and is a cofactor for numerous physiological enzymes involved in energy metabolism ¹⁷. According to preliminary preclinical and clinical studies, myocardial ischemia may be related to low magnesium levels ¹⁷. The outcomes of the Health Professionals Follow-up Study indicated a marginal inverse correlation between the consumption of magnesium and the occurrence of coronary heart disease in male subjects¹⁸. In healthy people, magnesium has been demonstrated to reduce the absorption of fat and ameliorate postprandial hyperlipidemia ¹⁹. About 9 and 20 mg of magnesium are found in each 30 g and half of an avocado, respectively ¹⁰.

Vitamin k1 (phylloquinone)

One of the limited alimentary sources that contains significant concentrations of both ascorbic acid and tocopherol is the avocado. In order to preserve circulatory antioxidant protection, vitamin C is essential for recycling vitamin E, which may help to reduce the pace at which LDL cholesterol oxidizes. Research points to vitamin C as a potential supporter of arterial plaque stabilization and vascular health ²⁰. Half an avocado (thirty grams) contains 1.34 and 0.59 mg of vitamin E (α -tocopherol), respectively ¹⁰. In hypercholesterolemic individuals, a randomized clinical trial indicated that vitamin C and E together could reduce the progression of atherosclerosis ²². In the biologically active form of certain proteins involved in blood coagulation and bone metabolism, vitamin K1 acts as a coenzyme ²³. Plant-based foods, specifically phylloquinone (K1), are thought to be the main source of vitamin K in the human diet. The reduced form of vitamin K1 functions as a cofactor for the coagulation enzymes ²⁴. Avocados provide 6.3 μ g and 14.3 μ g of vitamin K1 per 30 g and half of the fruit, respectively ¹⁰. While vitamin K intake worries some persons using anticoagulant medications, the amount of vitamin K1 in an avocado is 150 times lower per ounce than the 1000 μ g of K1 that could potentially interfere with the anticoagulant action of medications like warfarin (Coumadin) ^{25,26}.

B- Vitamins

Vitamin B-6 and folate deficiencies can raise homocysteine levels, which can worsen the health of vascular endothelial cells and raise the risk of cardiovascular disease (CVD) ^{27,28}. Avocados provide 0.20 mg of vitamin B-6 per half fruit, 27 μ g of folate, and 0.09 mg of vitamin B-6 per 30 g and 61 μ g of folate, respectively ¹⁰.

Phytochemicals

Carotenoid

The main avocado carotenoids are a subclass of fat-soluble antioxidants with oxygen content called xanthophylls ²⁹. Compared to carotenes, which include β -carotene, xanthophylls like lutein are more polar and so have a lesser propensity for pro-oxidant activity ³⁰. Among fruits and vegetables, avocados have the highest lipophilic total antioxidant capacity ³¹. The DASH diet pattern clinical study observed lower levels of oxidative stress (blood ORAC and urine isoprostanes) in a relatively healthy population when compared to a typical American diet, this is primarily because the DASH diet significantly increases serum carotenoids, particularly the xanthophyll carotenoids lutein, β -cryptoxanthin, and zeaxanthin, as a result of increased fruit and vegetable consumption ³². Xanthophylls seem to lower circulating oxidized low-density lipoprotein (LDL-C), which is a preliminary biomarker for the development and progression of vascular injury ³³. Higher levels of plasma xanthophylls were found to be negatively correlated with the development of carotid intima-media thickness in the Los Angeles Atherosclerosis Study, a prospective investigation whose findings may offer protection against early atherosclerosis ³³.

Eating avocados can be a significant way to obtain xanthophyll carotenoids through diet ³⁵. Hass avocado carotenoid content tends to rise dramatically from January to September ⁵. When harvest season begins. Xanthophylls, lutein and cryptoxanthin, make up the majority of the carotenoids in Hass avocados, accounting for around 90% of the total. The amounts of lutein, zeaxanthin, and cryptoxanthin per 30 g and half of a fruit are 81 μg and 185 μg , respectively, and 44 μg and 100 μg , respectively ¹⁰. However, xanthophylls were found in much higher concentrations in avocados after a more

comprehensive analysis was conducted. At harvest xanthophylls were found in 350-500 μ g per 30 g to 800-1100 μ g per half fruit ⁵. The hue of avocado flesh varies, appearing dark green below the surface, pale green in the middle, and yellow near the seed ⁴. The dark green peel had the highest quantities of total carotenoids ³⁶. In order for carotenoids to be released and solubilized for transfer into the gastrointestinal fat micelle and subsequently the circulatory system, intestinal absorption of carotenoids requires the presence of dietary fat ^{37, 38}. The distinct unsaturated oil and water matrix found in avocado fruit is created naturally to improve the absorption of carotenoids. Reduced-fat or fat-free salad dressings are widely available and have been demonstrated to dramatically lower carotenoid absorption when compared to full-fat dressings ³⁹. Salads are a substantial source of carotenoids. Similar clinical studies have shown that adding avocado to a salad without dressing or with a low-fat or fat-free dressing boosts the bioavailability of carotenoids by a factor of two to five ⁴⁰.

Phenolic

Fruit phenolics can lower the risk of CVD by improving blood flow and arterial endothelial health, lowering oxidative and inflammatory stress, and preventing platelet aggregation, all of which contribute to the maintenance of vascular health ^{41, 42, 43, 44}. A moderate amount of phenolic compounds may be found in avocados, with 60 mg and 140 mg of gallic acid equivalents (GAE) per 30 g and half of the fruit, respectively. Additionally, avocados contain a total of 600 μ mol Trolox Equivalent (TE) per 30 g, or 1350 μ mol TE for half of a fruit ³². Avocados fall around the middle of the fruit phenolic range according to this. The greatest fruit lipophilic antioxidant capacity is seen in

avocados, which may contribute to vascular health promotion and a decrease in serum lipid peroxidation ³².

Phytosterols

The highest known fruit source of phytosterols is avocados, containing roughly 26 and 57 mg of phytosterols per 30 g and half of the fruit, respectively ^{45,10}. Other fruits have roughly 3 mg of phytosterols per serving, which is a significant decrease ⁴⁵. The avocado's distinct emulsified lipid matrix and natural phytosterol glycosides may assist promote stronger intestinal cholesterol blocking activity than fortified foods and supplements, even if its phytosterol level is lower than that of fortified foods and dietary supplements ⁴⁶. Based on a recent economic evaluation conducted in Canada, foods containing phytosterols may have the potential to improve cardiovascular health and lower related medical expenses ⁴⁷.

Weight Management

There is a correlation between reduced weight and body mass index (BMI) and the availability and consumption of healthful foods, such as fruits and vegetables ^{47,49}. A prevalent notion has emerged over the last several decades positing that the consumption of foods with elevated fat content may contribute to weight gain, while low-fat dietary regimens are purported to more effectively promote weight management and reduce the risk of the onset of chronic diseases⁵⁰. On the other hand, a significant long-term, randomized clinical investigation revealed that a moderate fat diet can effectively contribute to weight loss and lower the chance of developing chronic illnesses ⁵¹. "Academic weight loss and weight maintenance are enhanced by dietary patterns with comparatively low energy density, according to strong and consistent evidence ⁵¹.

Significant weight reduction is linked to lowering food-based energy density by increasing the intake of fruits and/or vegetables, according to three randomized controlled weight loss trials ^{49,50,51}. By calculating the quotient of the aggregate caloric content and the overall mass of the consumed food, one may estimate the energy number of calories by the total weight of food ingested, one may estimate the energy density of a whole dietary pattern; low, medium, and high energy density diets have 1.3, 1.7 and 2.1 kcal per gram, respectively ⁵². Avocados possess a viscous aqueous matrix, dietary fiber, and fruit oil composition that appears to enhance the sensation of satiety in addition to having a medium energy density of 1.7 kcal/g ⁵³. This is in line with study which indicates that avocados, like other fruits, may help with weight control. In accordance with several preliminary investigations conducted during the initial trial, the effects of integrating 200 g of avocados into a dietary regimen aimed at weight reduction were examined. A total of 61 healthy, free-living individuals characterized as overweight or obese were randomly allocated to one of two groups in this research: one group was instructed to consume 200 g/d of avocados (providing 30.6 g of fat) as a substitute for 30 g of assorted fats, which included oil and margarine, while the alternative group refrained from avocado consumption for a duration of six weeks ⁵⁴. Avocados can be incorporated into a regimen aimed at weight reduction, as both cohorts exhibited similar decreases in weight, body mass index (BMI), and body fat percentage ($p < 0.001$) in clinical trials; thus, avocados may contribute to the management of weight ⁴⁸.

Healthy Aging

DNA Damage Protection

Similar to the phytochemicals found in avocados, xanthophylls may have antioxidant and DNA-protective properties as well as potentially protective effects against healthy aging, according to a number of clinical trials, one study included 82 male airline pilots and regular travelers who were exposed to high levels of cosmic ionizing radiation, which is known to damage DNA and may hasten aging⁵⁷. The incidence of chromosome translocation, a biomarker of cumulative DNA damage and the intake of vitamin C, beta-carotene, β -cryptoxanthin, and lutein-zeaxanthin from fruits and vegetables was found to be significantly and inversely connected with it ($p < 0.05$). In another experiment, there was an inverse correlation between plasma xanthophyll levels and lipid peroxidation (8-epi prostaglandin F2a)⁵⁷. In contrast to beta-carotene, lutein was found to have inverse correlations with oxidative DNA damage as determined by the comet assay in additional investigations^{59,60}. According to NHANES data, xanthophyll consumption declines with age⁶¹.

Osteoarthritis

Osteoarthritis (OA) is characterized by a progressive loss of joint cartilage and function, often leading to significant disability. This process is thought to be driven by oxidative and inflammatory stress, which disrupts the balance between biosynthesis and degradation of the extracellular matrix (ECM) in the joint. This imbalance contributes to the deterioration of cartilage, loss of joint integrity, and eventually, impaired function^{62,63}. Most people develop osteoarthritis (OA) as they age or gain weight or obesity. Oxidative and inflammatory stress may be the source of this joint deterioration, as

it can lead to an imbalance in biosynthesis and degradation of the extracellular matrix in the joint, ultimately resulting in loss of function^{62, 64, 65, 66, 67, 68}. The main carotenoids in avocados, lutein and zeaxanthin, have been linked in a cross-sectional study to a lower risk of cartilage abnormalities, an early sign of osteoarthritis (OA)⁶⁹. ASU, or avocado and soy unsaponifiables represent a composite of lipid-soluble extracts that possess a roughly established ratio of 1:2 (soy) for avocado. The main ingredients in ASU are thought to be anti-inflammatory substances with antioxidant and analgesic properties^{62,70,71,72,73,74, 75}. Pretreatment of chondrocytes with ASU was observed to prevent the activation of COX-2 transcripts and the secretion of prostaglandin E2 (PGE2) returned to baseline levels after stimulation with lipopolysaccharide (LPS) in in vitro experiments. Subsequent investigations revealed that ASU possesses the capability to downregulate the expression of inducible nitric oxide synthase (iNOS), interleukin-1 beta (IL-1 β), and tumor necrosis factor-alpha (TNF- α) to levels that are analogous to those observed in nonactivated control cultures. Ongoing laboratory investigations suggest that ASU may influence osteoblasts to aid in the healing of OA cartilage⁶².

Eye Health

The macula of the eye, which represents the region where light is concentrated through the lens, is the site at which lutein and zeaxanthin are selectively absorbed⁷⁶. Age-related reductions in relative lutein and zeaxanthin intakes are observed, with lower levels in females than in males⁶¹. Mexican Americans are among the biggest avocado consumers in the country and have the greatest intake of lutein and zeaxanthin of any ethnic group. Research indicates that insufficient dietary consumption and diminished plasma levels of lutein may aggravate age-associated visual deterioration, as evidenced by

observational studies ^{77, 78, 79, 80}. Diets high in MUFAs were found to be protective against age-related eye impairment^{79,80}. Because avocados assist increase the absorption of carotenoid from other fruits and vegetables and contain a combination of MUFA and lutein/zeaxanthin, they may be beneficial to eye health ⁸¹. The concentration of lutein and zeaxanthin present in avocados is quantified at 185 µg per half of the fruit, which is expected to exhibit a higher degree of bioavailability compared to the majority of alternative fruit and vegetable sources.

Skin Health

The skin typically exhibits the first discernible indications of ageing. Applying topically or consuming specific fruits, vegetables, or their extracts – like avocado – has been suggested for skin health ^{81,82}. The persistent oxidative and inflammatory damage that exposure to ultraviolet (UV) and visible radiation causes to the skin on the face may be prevented by carotenoids. A clinical study found that the concentration of carotenoids in the skin is directly correlated with the quantity of fruits and vegetables consumed. Avocados contain highly accessible lutein and zeaxanthin, which may help protect the skin from UV and visual radiation ⁸³. The highly bioavailable lutein and zeaxanthin found in avocados may be helpful to shield the skin from visual and ultraviolet rays ⁸¹. There are a few tiny studies that indicate lutein applied topically orally may have photoprotective effects ^{84, 85, 82}. A cross-sectional study looked at the connection between dietary choices and skin anti-aging in 716 Japanese women ⁸⁶. Following the adjustment for confounders such as age, smoking status, BMI, and lifetime sun exposure, the findings demonstrated a significant correlation between increased intakes of total dietary fat and increased skin elasticity. There was a substantial correlation between less wrinkles and eating more

green and yellow veggies ⁸⁶. Several preclinical studies suggest that avocado components may improve wound healing activity and reduce UV damage, thereby protecting skin health ^{87,88}.

Cancer

Numerous bioactive phytochemicals found in avocados, such as phenols, glutathione, D-mannoheptulose, terpenoids, carotenoids, and persenone A and B, have been shown to have anti-carcinogenic qualities ^{89,90}. Some of these phytochemicals may have therapeutic value based on the amounts found in avocados ⁹¹. Direct avocado anti-cancer efficacy is still in its very early stages because all of the data is based on in vitro studies using human cancer cell lines. Cancers of the larynx, pharynx, and oral cavity are the main focus of avocado cancer research. An antioxidant is glutathione. Glutamic acid, cysteine, and glycine are the three amino acids that make up this tripeptide ⁹¹.

With 8.4 mg per 30 g or 19 mg per half fruit, avocados have glutathione levels that are several times higher than those of other fruits ⁹¹. A large population-based case-controlled study found strong correlation between higher glutathione intakes and a lower incidence of oral and throat cancer, even though eating breaks down glutathione into individual amino acids ⁹². A clinical study found that when plasma lutein and total xanthophylls were present but not individual or total carotenes, patients with early-stage (In situ, stage I, or stage II) cancer of the larynx, pharynx, or oral cavity showed lower urinary concentrations of both total F2-isoprostanes and 8-epi-prostaglandin⁵⁸. Preclinical research has demonstrated the anti-*Helicobacter pylori* activity of avocado extracts rich in xanthophyll, suggesting that these extracts may have an impact on gastritis ulcers, which may raise the risk of stomach cancer ⁹². Dietary carotenoids exhibit biological properties

that may protect against breast cancer, including as inducing apoptosis, inhibiting the growth of mammary cells, and acting as antioxidants ⁹². There have been few and inconsistently reported studies looking at the relationship between carotenoid intake and the recurrence of breast cancer and the consumption of fruits and vegetables ⁹². Lutein and total carotenoids seem to lessen oxidative stress, which may be a cause of breast cancer ⁸⁹. Total plasma carotenoid concentrations and oxidative stress were found to be significantly inversely correlated in women who had previously had treatment for breast cancer. One of the best indicators of breast cancer risk is mammographic density ^{92, 93}. In the Nurses' Health Study, circulating carotenoids levels and mammography density were prospectively evaluated in 626 controls and 604 cases of breast cancer, forming a nested case-control study ⁹³. It was investigated how mammographic density related to carotenoids and breast cancer risk. Overall, there was an adverse relationship ($p=0.01$) between the total amount of carotenoids in the blood and the incidence of breast cancer. Women in the highest tertile of mammography density had a 40-50% lower risk of breast cancer ($p<0.05$) when their blood levels of α -carotene, β -cryptoxanthin, lycopene, and lutein/zeaxanthin were elevated. On the other hand, there was no negative correlation found between women's risk of breast cancer and carotenoid having a poor density of mammography. These findings imply that carotenoids' plasma levels may help lower the risk of breast cancer, especially in women who have high mammographic densities. Avocado lipid extracts may have antiproliferative and anticancer properties, according to exploratory research conducted on prostate cancer cell lines ³⁶. Among the recognized active ingredients is lutein. There aren't any human studies to support this theory linking lutein to prostate cancer at the moment.

2.1.2 Avocado Seed Profile

Avocado seeds are typically thrown away, since there hasn't been much usage of this by-product, there has been severe environmental damage ⁹⁴. An economic and environmental viewpoint would be advantageous for efficient waste by-product management ⁹⁵. Minerals, vitamins, proteins, lipids, and polysaccharides are among the many bioactive and functional components found in avocado seeds, which make up a sizeable amount (13 – 17%) of the fruit ⁹⁶⁻⁹⁷. Avocado seeds are rich in bioactive substances such as flavonoids, condensed tannins, and phenolics. These extracts have been tested for a variety of traditional dermatological applications, including anti-hyperglycemic, anti-cancer, anti-inflammatory, antihypercholesterolemia, anti-oxidant, anti-microbial, and anti-neurogenerative properties ⁹⁷⁻¹⁰². Because they don't contain any hazardous or harmful substances, the food, pharmaceutical, and cosmetics industries can obtain biologically active components from them in a natural way ⁹⁷. Furthermore, due to their strong antioxidant capacity, they stop food oxidation, which is the process by which proteins, vitamins, carbohydrates, and lipids are broken down by reactive nitrogen and oxygen species, which alter food's sensory and nutritional qualities and other culinary item attributes ¹⁰³. Investigating seeds potential as a viable source of naturally occurring bioactive components can result in the development of a novel product with additional value and a secure substitute for manufactured substances. Furthermore, the industry that processes avocados and the environmental advantages are greatly impacted by the value of avocado seed residue ¹⁰⁴.

2.1.3 Nutritional Profile of Avocado Seed

Avocado seeds are abundant in protein, carbohydrates, fats, crude fiber, vitamins, minerals, and a wide range of phytochemicals, among other nutritious and functional compounds.

Carbohydrates

The majority of the macromolecules present in avocado seeds are about 64.9% which are thought to be carbs of the total carbohydrates in avocado seeds ¹⁰⁵. Starch accounts for 91.2%, plant-based polysaccharide fractions have been shown to have a range of biological functions ¹⁰⁶. Avocado seeds contained high concentrations of the two C7 sugars, D-mannoheptulose (63.8 mg/g) and perseitol (88.3 mg/g) ¹⁰⁷. The predominance of these C7 sugars in avocado seeds points to their importance in these tissues. These sugars might serve as transport and storage sugars in avocados ³¹⁶. Perseitol's involvement as a C7 carbon storage molecule in avocado cotyledons is indicated by its abundance among all sugars at physiological maturity. Avocado seed's carbohydrate composition was 246.1 mg/g of dry weight (DW) for starch, 18.5 mg/g for sugar, 1.9 mg/g for hexose, 63.8 mg/g for D-mannoheptulose, and 88.3 mg/g for perseitol ^{107,108}. 36.3% of the total sugar content in the avocado seed was discovered to be C7 sugar. Avocado seeds contain arrange of sugars, including fructose (12.93), glucose (5.62), sucrose (7.86), D-mannoheptulose (10.51), and perseitol (12.54 mg/g of DW), which is similar to the results of the prior study ¹⁰⁹.

Lipids

Avocado seeds have a total lipid (TL) level of 1.1%–1.6% ¹¹⁰. Thin-layer chromatography was used to further analyze the TL and found that it included 7.4–

10.9%, 12. –13.2, and 77.1–80.3% of neutral lipid, glycolipid (GL), and phospholipid (PL), respectively. The composition of GL reported by the authors was 17.5–18.5 (acylsterylglucoside), 56.3–57.7 (monogalactosyl–diacylglycerol), 10.1–10.8 (sterylglucoside), 9.8–10.7 (cerebroside), 1.7–2.0 (digalactosyl–diacylglycerol), and 1.9–2.4 % (others) ³¹⁷. Phosphatidic acid makes up 14.5–17.5 of the glycerol (10.5–13.4), phosphatidylcholine (28.1–31.4), phosphatidylinositol (3.6–4.2), and other substances (6.3–6.9%) of the total PL. An analysis of the fatty acid composition of avocado seeds revealed that the most prevalent fatty acid is linoleic acid (35–38%), which is followed by oleic acid (22–24%) and palmitic acid (17–19%). In an analogous fashion, utilized Gas Chromatography-Mass Spectrometry (GC-MS) to analyze the fatty acid composition within the lipid-dense extract of avocado seeds. Among the fatty acids documented in their findings were palmitic acid (7.1 µg/g), nervonic acid (2.88 µg/g), arachidic acid (2.39 µg/g), linoleic acid (4.06 µg/g), oleic acid (5.32 µg/g), stearic acid (5.06 µg/g), myristic acid (2.49 µg/g), erucic acid (3.63 µg/g), and tetracosanoic acid (4.29 µg/g), alongside their respective derivatives, which encompassed avocations (32.28 µg/g), persins (10.12 µg/g), polyhydroxy fatty acids (24.26 µg/g), and pahuatins (4.26 µg/g) ³¹⁸. These results indicate that the avocado seed extract contains high levels of fatty acids, including oleic, linoleic, and palmitic acid, as well as its derivatives, including fatty acid alcohols, acetogenins, pahuatins, persins, and avocatinins. ¹¹¹.

Protein

Of the many macromolecules included in avocado seeds, protein accounts for a substantial fraction ¹¹². Proteins are large, complex molecules made of amino acids that

are necessary for enzyme control, growth and development, cell signaling, and biocatalysis ³¹⁹. The rising demand for food that is higher in nutrients has brought attention to plant-based nutrients, particularly protein. As a result, locating sustainable, alternative, and highly nutritious food sources has received a lot of attention ¹¹³. The protein content of avocado seeds has been reported in a number of studies to be 23% , 17.94% , 15.55 % , 7.75 % , and 2.64 %¹¹⁴⁻¹¹⁷. Because avocado seeds contain a composition of PL, phosphatidyl ethanolamine (30.7–31.9), phosphatidyl significant number of nutrients, such as protein, carbohydrates, and dietary fibers, it may be appropriate to use them in human supplements ¹¹⁶. More work is needed to identify the amino acid and protein profiles of avocado seeds because there aren't many study publications on the measured amino acids and protein in them.

Minerals and Vitamins

The avocado seeds are a rich source of various minerals, namely phosphorus (P), calcium (Ca), potassium (K), iron (Fe), sodium (Na), zinc (Zn), copper (Cu), cobalt(Co), and lead (Pb), and vitamins including vitamin A, thiamine (B1), riboflavin (B2), niacin (B3), VitaminC and vitamin E. found the concentration of various minerals, namely, P, Ca, Na, and Zn as 4.16, 0.09, 0.82, 1.41, and 0.18 mg per 100 g of the avocado seed, respectively ¹¹⁴. Because avocado seeds contain nutrients, they are a better option for human and animal nutrition when there is a micronutrient deficit, establish that there were 10 (A), 0.33 (B1), 0.29 (B2), 0.06 (C), and 0.12 (E) mg of different vitamins in 100 g of avocado seed ^{118,119}. The immune system, blood vessels, and eyesight may all benefit from the vitamins A, C, and E found in avocado seeds. On the other hand, vitamin B has

been shown to play a significant role in enhancing blood circulation, relaxing nerves, and stimulating cognitive function.

2.1.4 Bioactive compounds in avocado seeds

Recent studies and reviews on the use of horticulture crop byproducts have demonstrated that phytochemicals and their health-promoting properties may increase their usage in the creation of novel foods ^{106, 120}. This will lower the cost of disposing of the byproducts and increase the farmers' overall profitability. When it comes to phenolics, avocado seeds have many times more than common antioxidant sources like raw blueberries ¹²¹. It is made up of phenolics from five different groups: flavonols, hydroxycinnamic, procyanidins, catechins, and hydroxybenzoic acids ¹²². Additionally, it was observed that 9.5 and 13.04 mg CE/g dry weight (DW) in the avocado types known as Hass and Shephard. Conversely, reported comparatively high GAE/g of DW ^{123, 124} levels of 88.2 mg. Agronomic conditions, fruit species, soil type, and post-harvest processing are all considered contributing factors to the diversity in the bioactive profile ¹²⁵. Using chromatographic analysis, retention periods, and UV spectra features, certain phenolics in avocado seeds were found. Four phenolic substances were found by the authors: procyanidin B1, epicatechin, trans-5-O-caffeoyl-D-quinic acid, and catechin. After looking into the volatile components of the seed extracts, it was discovered that esters of fatty acids and their derivatives as well as isoprenoid derivatives were present ¹⁰¹. Seven compounds were found under the category of terpenoid and phenylpropanoid compounds, which includes estragole, isoestragole, cubebene, α -cubebene, α -germacrene, α -farnesene, and caryophyllene. The lipid fraction of avocado seeds includes polyhydroxylated fatty alcohol (PHFA) derivatives as a significant component. Commonly acylated fatty

alcohols with unsaturated aliphatic chains are the source of acetogenins, a form of polyhydroxyalkanoates (PHFA). There were differences in the total acetogenin content of avocado seed amongst 22 cultivars, ranging from 1090 to 8330 $\mu\text{g/g}$ DW. The avocado seeds' acetogenin profile was primarily influenced by persenone A& B, AcO-avocadene, and then by persenone C, AcO-avocadenyne, persin, and persediene

¹²⁵. Other trace elements found in avocado seeds are alkaloids, phytosterols, and tocopherols.

2.1.5 Health-related bioactive properties of avocado seed extracts

The food, nutraceutical, and pharmaceutical sectors have turned their primary research focus to the separation and identification of functional components from natural resources because of their significance for human health. This is due to the fact that these elements are involved in a number of biological and health-promoting bodily functions. Avocado seeds are used medicinally because they contain a lot of polyphenols.

Anticancer Activity

With 9.6 million deaths from cancer worldwide, the disease has emerged as a major health concern. The global cancer burden is now 18.1 million ¹²⁶. The hallmark of cancer is the development and proliferation of aberrant cells that expand outward and infiltrate nearby tissues ¹²⁷. Clinical research has revealed that synthetic anti-tumor drugs may have therapeutic benefits, but they can significantly damage normal cells, endangering human health. Plant-based antitumor medications are becoming more popular due to their lower toxicity and safety as well as their ability to strengthen human immunity. In human and animal cell lines, the biologically active components of avocado seeds demonstrated anti-

cancer potential against cancerous conditions such as prostate and lung cancer, breast cancer, colon cancer cells, and hepatocellular carcinoma ^{99,128,129}.

Avocado seed polyphenols have the ability to inhibit human prostate cancer cells (LNCaP), breast cancer cells (MCF7), lung cancer cells (H1299), and colon cancer cells (HT29) in a dose-dependent manner, with inhibitory rates of 19, 19.1, 67.6, and 132.2 $\mu\text{g}/\text{mL}$ ⁹⁹. The scientists clarified that by suppressing the expression of cyclin D1 and E2 in prostate cancer cells, extracts from avocado seeds caused G0/G1 cell cycle arrest. Moreover, individuals who applied methanolic extracts of avocado seeds on breast cancer cell lines (MDA-MB-231) demonstrated comparable outcomes. Apoptosis was caused by seed extracts' (0.1 mg/mL) enhanced activation of caspase-3 and its target protein, poly (ADP-ribose) polymerase (PARP) ¹³⁰. Avocado seed ethanolic extracts activated caspase-3, transcription factor p53, and depolarized the mitochondrial membrane, leading to the predominance of apoptosis-inducing factor along with apoptosis in Jurkat lymphoblastic leukemia cells in an oxidative stress-dependent manner ¹³¹.

Avocado seeds have the potential to limit the growth of immortalized HaCaT keratinocytes through the action of proanthocyanidins B1, B2, and A-type trimer ¹³². Avocado seeds contain a significant secondary metabolite called triterpenoid, which has anticancer properties ¹³³. HepG2 and HCT116 cancer cells were the focus of lipidic preparations from avocado seeds that were found to have anticancer properties. The authors reported that, in comparison to avocado fruit lipids at a concentration of 100 μL , seed lipids showed an inhibitory proportion of 65 and 58% in HCT116 and HepG2 cancer cell lines ¹²⁸. Studies using ethnopharmacology have shown that avocado seeds cause MCF-7 cell lines to undergo apoptosis and cytotoxicity. The authors used flow

cytometric analysis to look at apoptosis and the MTT assay to look at cytotoxic activities. Chloroform extract exhibited strong cytotoxicity against MCF-7 cancer cell lines, as demonstrated by the cytotoxic test, which had an IC₅₀ value of 94.9 µg/mL. Furthermore, higher cytotoxicity was noted for the methanol-soluble and non-soluble forms, with IC₅₀ values of 34.5 and 66.0 µg/mL, respectively. According to a flow cytometry study, MCF-7 cells' sub-G1 phase arrest was modulated by the methanolic fraction, which led to apoptosis. Additionally, avocado seed lipidic extract has cytotoxic effects on colorectal cancer. Avocado seeds' avocatin and polyhydroxylated fatty alcohols have been linked to a potential cytotoxic effect on Caco-2 cells¹³⁴. These substances activated caspases 8 and 9, which caused apoptosis. Extracts have the ability to decrease the potential of the mitochondrial membrane, prevent the oxidation of fatty acids, and raise the levels of reactive oxygen species (ROS) and superoxide anion (O₂⁻). Furthermore, lipidic extracts promoted the release of IL-6, IL-8, and IL-10 cytokines, but IL-1β secretion was suppressed.

Antidiabetic Activity

Diabetes mellitus is a common genetic disorder caused by the impairment of insulin secretion and its deficiency. Diabetes mellitus had reached epidemic levels worldwide. Currently, 463 million people and about 10% (USD 760 billion) of global health expenditures are on diabetes¹³⁵. Insulin deficiency disrupts the metabolism of fats, proteins, and carbohydrates, resulting in chronic hyperglycemia, changes in lifestyle and the development of healthy behaviors can postpone and manage type 2 diabetes. Natural anti-diabetic products may be a good way to manage diabetes with the least amount of side effects¹³⁶.

By targeting peroxisome proliferator-activated receptor-gamma in a manner similar to that of an anti-diabetic medication (thiazolidiones), avocado seeds aid in the treatment of type 2 diabetes ¹³⁷. When avocado seeds (2–8%) were introduced to a high-sugar diet, it had an anti-diabetic and lipid-reducing effect by lowering cholesterol and blood glucose in spontaneously hypertensive rats. The impact of reducing blood glucose was ascribed to bioactive substances that facilitate the conversion of glucose into glycogen within the hepatic cells ¹⁰⁰. Treatment with 300 or 600 mg/kg body weight avocado seed extract decreased glycemia (>70%) and repaired damage to pancreatic islet cells in alloxan-induced diabetic rats ¹³⁸. The blood glucose of diabetic rats was dramatically reduced when 40 g/L of hot aqueous avocado seed extracts and glibenclamide (5 mg/kg) were added to Wistar albino rats that had been exposed to alloxan. On day 14, the reference medication glibenclamide had the most response (58.9%), which is comparable to the reaction of 40 g/L avocado seed extraction on day 21 ¹³⁹. The normal control rats had intact pancreatic islets and exocrine cells, as per the findings of pancreas histology. Rats with diabetes caused by alloxan (diabetic control rats) had decreased islet cell counts and areas of necrosis. When diabetic rats were given the 20 g/L extracts, their preserved islet cells were smaller than those of the untreated alloxan-induced diabetic rats. Further research is necessary, as the aforementioned studies have shown that avocado seed extract may have anti-diabetic properties.

Antioxidant Activity

Free radicals are a byproduct of oxidative stress and the autoxidation of human lipids and lipoproteins. These pathologies include diabetes, cancer, heart disease, neurological problems, and many more ^{140,141}. The use of natural plant antioxidants, such as alkaloids,

flavonoids, and polyphenols, to address these health issues is becoming more and more popular every day ^{141,106}. These substances have demonstrated promising potential in lowering oxidative stress, preventing many diseases, preserving health, and postponing the aging process. They can also bind catalytic metals and quench free radicals ¹⁴². Avocado seeds exhibit their antioxidant activity in vitro through the stabilization of peroxy radicals, superoxide anions, DPPH, and ABTS, as well as their ferric reducing power. Furthermore, they prevent β -carotene from blanching and the production of reactive chemicals with thiobarbituric acid⁹⁷. Coloured avocado seed extracts showed an oxygen radical absorbance capacity (ORAC) of 2012 Trolox equivalents/mg, and an electron paramagnetic resonance spectroscopy investigation showed that the seed extracts could scavenge radicals with an EC50 of 42.1 $\mu\text{g}/\text{m}$ ⁹⁹. According to the oxidation induction time (ORI), a dose of 0.75 percent avocado seed extracts results in an oxidation delay of 80 percent ¹⁴³. Avocado seed aqueous extracts have antioxidant activity and can stop oxidative damage brought on by radicals ¹⁴⁴. Rat brains were stimulated by the authors using sodium nitroprusside (SNP) solutions and Fe²⁺. An increase in thiobarbiturate reactive species (TBARS) was observed, resulting in oxidative damage caused by free radicals generated by Fe²⁺ and SNP. Furthermore, because phenolic components work in concert, avocado seed extract showed reduced levels of TBARS in Fe²⁺ and SNP- induced lipid peroxidation ³²⁰.

Procyanidins (catechin and epicatechin) and phenolic components in avocado seeds account for 38% of the fruit's antioxidant activity ¹²¹. Numerous phenolic components were present in the ethanolic extracts of Hass and Fuerte avocado seeds ⁹⁷. The antioxidant potential of Hass and Fuerte peel extracts has been reported to be 1175.1 and

1881.4 $\mu\text{mol Fe}^{2+}/\text{g}$, respectively. They discovered that superoxide anions (O_2^-) and peroxy radicals (ROO^\bullet) may be stabilized by epicatechin and catechin found in seeds. Interestingly, compared to epicatechin, catechin displayed stabilizing action that was 1.3, 2.5, and 1.6 times more for ROO^\bullet , O_2^- , and hypochlorous reactive species. To assess the delay in oxidation, lyophilized avocado seed powder was added to oil in water emulsion and beef meat burgers ¹⁴⁵. They saw 90% suppression of TBAR compounds in meat burgers and 30% inhibition of oxidation in emulsion for pure extracts and 60% inhibition in extract plus egg albumin. The scientists proposed using avocado seeds to extend the shelf life of meat. Avocado seed volatile or lipophilic chemical composition suggests that they could be used as an antioxidant addition ¹⁰¹. The total phenolic content and DPPH inhibition of avocado seed extracts in acetone and ethanolic extracts were 30.80 and 30.25 GAE/100 g, respectively, and 212.75 and 183.75 mg Trolox/100 g, respectively. Additionally, compared to ethanol extract (45.05 g AAE/100 g), avocado seed acetone extract showed a larger power reduction of 56.35 ascorbic acid equivalents (AAE)/100 g. As a result, it's possible that avocado seeds could be included in cuisine as an antioxidant addition.

Anti-neurogenetic

Alzheimer's disease (AD) is a brain that impairs cognition as a result of a gradual and irreversible loss of nerve cells ¹⁴⁴. In Alzheimer's sufferers, acetylcholine deficiency may prevent brain transmission ¹⁴⁶. Thus, the current treatment for Alzheimer's and other neurodegenerative diseases involves blocking AChE and BChE using phytoconstituents derived from plants in order to restore acetylcholine. Aqueous extracts from avocado seeds inhibited the AChE and BChE enzymes having, respectively, IC₅₀ values of 27.93

and 30.08 mg/mL¹⁴⁴. Butyrylcholine and acetylcholine are broken down by both enzymes when phenolic chemicals like caffeic acid in avocado seeds inhibit them. This causes an increase in these neurotransmitters at the synaptic clefts. In the end, this facilitates better nerve cell communication and aids in the treatment of neurodegenerative diseases like AD.

Anti-inflammatory

An inflammatory response is a person's way of defending themselves against outside threats. It involves a variety of chemical mediators, including defense cell recruitment and plasma protein extravasation, which can cause vascular alterations⁹⁷.

Anti-microbial Activity

Natural substitutes for the synthetic antibacterial used in food, medicine, and pharmaceuticals has been the subject of numerous investigations. Concerns raised by customers about the safety of products containing synthetic chemicals have prompted these efforts. Avocado seeds have been touted by numerous scientists as having the ability to reduce human food-borne pathogenic germs and spoilage microbes found that the organic extracts from avocado seeds inhibited microorganisms such as *S. aureus*, *S. pyogenes*, *C. ulcerans*, *C. albicans*, *E. coli*, and *S. typhi*, as well as *Candida spp.*, *Cryptococcus neoformans*, and *Malasseziapachydermatis*^{14,148}. Furthermore, petroleum ether extracts showed inhibitory action against *S. aureus*, with an IC₅₀ of 8.7 µg/mL, while methanolic and chloroform extracts of avocado seeds shown antifungal capability against *Cryptococcus neoformans* with IC₅₀ values of less than 8 µg/mL and 8.211 µg/MI¹⁴⁹. Additionally noted that seeds for *G. lamblia* 150 and *E. histolytica* showed

anti-parasitic action, Avocado seeds have derivatives of fatty acids has the ability to combat microbes, known as acetogenins.

The initial investigation concerning the antilisterial properties of avocado acetogenins ascertained that avocado seeds comprised AcO-avocadene, persediene, persenone C, persenone A, persin, and persenone B; furthermore, it was established that the most efficacious acetogenins were AcO-avocadenyne, persenone C, and persenone A. Additionally, the acetogenin extracts exhibited bactericidal properties through an augmentation of membrane permeability, which culminated in cell lysis, with a minimum inhibitory concentration quantified at 7.8 mg/L.¹⁵¹ The amount of unsaturated molecules in the aliphatic chain and the trans-enone characteristic work together to produce antilisterial activity. In another study, the natural lipidic molecules of avocado seeds called acetogenins (AcO-avocadene, AcO-avocadenyne, persediene, persenone A, persenone B, persenone C, and others) were assessed for their ability to regulate the growth and endospore germination of *Clostridium sporogenes* PA 3679 (ATCC7955) in carrot puree at high hydrostatic pressure (HHP) (300–600 MPa), time (3-6 min), temperature (25–120 °C), and salt (1%–3%). According to the authors, AcO-avocadene showed the strongest antibacterial activity. The extract also shown better stability at pH \geq 7.0 and resistance to high temperature, HHP, and salt. But over 42 days, at 25 and 4 0C, acetogenins were decreased by 63 and 32%, respectively. The most stable acetogenin was persediene, which was followed in stability by persenones and AcO-avocadene. Transenone in C-4, an aliphatic chain, or a keto group allow hydrogen donation to a carbon atom and block oxidation ¹⁵². A study to assess the acetogenins in avocado seeds'antibacterial spectrum ¹⁰². They introduced pure acetogenins to beef that had been

infected with *Listeria monocytogenes* and kept it between 20 and 4 °C. For a comparison study, they exposed eight gram-positive bacteria to food preservatives Nisaplin and Mirenat. The scientists came to the conclusion that avocado seeds' acetogenin inhibitory zone was two to four times larger than Other than *Staphylococcus aureus*, Nisaplin® and Mirenat® are effective against gram + ve bacteria. Furthermore, acetogenins totally inhibited *L. monocytogenes* after being stored at 4 °C for 72 days. According to them, avocado seeds are a good source of useful chemicals that may have antibacterial properties. Sesquiterpenoids, poly, and unsaturated fatty acid esters were found in avocado seed based on chemical profiling of volatile chemicals ¹²⁵.

According to their findings, avocado seeds' fatty acids have antibacterial properties. Double bonding exists in the cis-configuration of the fatty acid. By causing the phospholipid chain to become disorganized, they change the way the cell functions by causing the cell membrane to become fluid, disintegrate, and leak intracellular material, ultimately leading to cell death. Maximum reductions in microbial populations of 4 and 1.8 log cycles were recorded for *Staphylococcus aureus* and *Salmonella enterica* serovar typhimurium, respectively, at an elevated concentration of 2000 mg/L¹²⁵. They clarified that the composition and structure of the cell wall may be the cause of the minimal microbial decrease for *S. typhimurium*. Gram-negative bacteria have a lipidic bilayer that shields them more against antibacterial substances ¹⁵³.

2.2 Components of a Healthy Diet and The Associated Advantages

A healthy diet is characterized by its ability to furnish sufficient vitamins and hydration to satisfy the physiological requirements of the human body, alongside providing

appropriate quantities of macronutrients to support both energetic and physiological demands without leading to excessive intake¹⁵⁴. Carbohydrates, proteins, and lipids are classified as macronutrients, and they are essential for delivering the energy requisite for the cellular processes integral to daily functioning. one that provides enough vitamins and water to meet the body's physiologic needs, as well as adequate amounts of macronutrients to sustain energetic and physiological needs without excess consumption¹⁵⁵. For appropriate growth, development, metabolism, and physiological functioning, relatively minimal levels of micronutrients that is, vitamins and minerals are needed ^{156,157}. The main energy source in the diet is carbohydrates, which are present in the highest concentration in vegetables, fruits, cereals, and legumes ¹⁵⁸. When it comes to obtaining health benefits, whole grains are better than processed grains because the latter have less fiber and micronutrients because they were stripped of their germ and bran during the milling process ¹⁵⁹. Elevated consumption of whole grains has been correlated, according to meta-analyses of prospective cohort studies, with a diminished risk of mortality from all causes, including cardiovascular ailments, neoplastic diseases, respiratory disorders, diabetes mellitus, and infectious diseases, in addition to a reduced risk of coronary artery disease, cerebrovascular accidents, cardiovascular conditions, and neoplastic diseases ¹⁵⁹⁻¹⁶¹.

In addition to providing energy, fresh fruits and vegetables also contain dietary fiber, which helps with gastrointestinal motility, cholesterol reduction, and glyceemic control ¹⁶². Moreover, the consumption of fresh fruits and vegetables serves as a crucial source of phytochemicals (including carotenoids, phytosterols, and polyphenols), which are considered bioactive compounds believed to contribute significantly to numerous

health benefits associated with a diet rich in fruits and vegetables ¹⁶³. Although the exact mechanisms behind the actions of these diverse phytochemicals are unknown, they are recognized for their antioxidative properties and their capacity to modulate nuclear transcription factors, lipid metabolism, and inflammatory mediators. For example, flavonoids have been shown to diminish insulin resistance and enhance insulin secretion, suggesting that these phytochemicals may possess certain benefits in the management of diabetes and obesity ¹⁶⁴.

Furthermore, polyphenols have a bidirectional interaction with the gastrointestinal microbiota, promoting gut bacteria and being broken down by them into further bioactive chemicals ¹⁶⁴. The intake of fruits and vegetables has been shown to exhibit an inverse relationship with the incidence of non-communicable diseases (NCDs), including but not limited to metabolic syndrome, hypertension, cardiovascular diseases, chronic obstructive pulmonary disease, and lung cancer ¹⁶⁵⁻¹⁷⁰. Dietary proteins serve as a vital source of energy and amino acids, encompassing those that are essential for the body but cannot be synthesized endogenously. Dietary proteins come from two sources: plants (legumes, soy products, grains, nuts, and seeds) and animals (meat, dairy, fish, and eggs) ³²¹. The former is thought to be a richer supply because of its wide range of amino acids, high digestibility, and higher bioavailability ¹⁷¹. Saturated fatty acids, on the other hand, are found in animal-based protein sources and have been connected to dyslipidemia, cardiovascular disease, and several types of cancer. Red meat in general and processed meat in particular have been linked to an increased risk of colorectal cancer ^{172,173}, even if the exact processes remain unknown. Additionally, eating foods high in acidic foods like animal-derived proteins can cause the body's acid-base balance to shift towards

acidosis^{174, 175}. Urinary calcium stones, insulin resistance, and poor glucose homeostasis have all been related to elevated metabolic acid load^{174,175}. For the duration of one's life, sustaining lean body mass requires an adequate consumption of protein from food. Protein is crucial for maintaining bone mass, lowering fracture risk, and avoiding age-related loss of skeletal muscle mass in older adults^{176,177}. Supplementing with amino acids can enhance strength and functional status in older adults who do not get enough protein from their diets¹⁷⁸. Lipids, often known as fats, serve as the main structural elements of cell membranes and are also a source of cellular energy¹⁸⁰. There are four types of dietary fats: saturated fats, trans fats, polyunsaturated fats, and monounsaturated fats. Food's fat content is often a combination of these several kinds¹⁷⁹. Many foods, such as fish, nuts, seeds, and oils produced from plants, include unsaturated fats, but a higher proportion of saturated fats are found in animal products and certain plant-derived oils^{179,180}. The majority of trans fats in diet come from processing vegetable oils, yet there are also trace amounts of trans fats from ruminant animals including cows, sheep, and goats^{180,181}. Among the various categories of dietary lipids, unsaturated fats exhibit an association with reduced incidences of cardiovascular disease and mortality, whereas trans fats, and to a lesser extent, saturated fats, are correlated with detrimental health outcomes, including an elevated risk of death^{179,180}. Since the two classifications of polyunsaturated fatty acids—omega-3 and omega-6—are typically not synthesized by the human body and must therefore be acquired through dietary intake, they are classified as essential fatty acids¹⁵⁴. A multitude of research investigations has been conducted to explore the potential health advantages associated with omega-3 fatty acids, particularly eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). The evidence suggests

that these fatty acids may have positive effects on cardiovascular health, prevent cognitive decline, reduce inflammation, sustain muscle mass, and improve systemic insulin resistance ¹⁸³⁻¹⁸⁴. Oily fish, in particular, is a good source of EPA and DHA, and supplements are easily accessible for people whose diets do not include enough of these nutrients ^{185,186}. Nuts, seeds, and different plant oils include alpha-linolenic acid, the main omega-3 fatty acid present in plants ¹⁸⁷. Micronutrients are required in trace levels, as opposed to macronutrients, but they are crucial for healthy growth, metabolism, physiological functions, and cellular integrity ^{156,157}. The micronutrient quality of the current Western diet has decreased due to the transition from whole foods to processed and refined foods ¹⁸⁸. The deficiency of specific vitamins and minerals has been correlated with persistent metabolic dysfunction and cellular senescence in late-onset pathologies. In light of these revelations, it has been suggested that the adequate intake of antioxidant-rich micronutrients through dietary sources or supplementation (including but not limited to copper, zinc, selenium, as well as vitamins A, C, and E) may mitigate the likelihood of developing age-associated ailments and decelerate their progression.³²²

Water makes up the majority of the body's overall weight and lean body mass, making it the primary component of the body ¹⁵⁷. In addition to being a source of hydration, water also contains trace elements and electrolytes, among other micronutrients ^{190, 191}. Up to 20% of the daily required intake of calcium and magnesium can be obtained by drinking water ¹⁹¹. Our knowledge of the amount of water needed and its impact on health and disease is restricted, but the rise in high-calorie beverage consumption around the world has brought attention back to the significance of water for preserving health and avoiding illness ¹⁹⁰.

2.3 Potential Bioactive Components in Fruit

The prospective physiologically active substances that were isolated from fruit and vegetable waste are a fascinating group of molecules that comprise pigments, enzymes, phenolic compounds, dietary fiber, antioxidants, and antibacterial agents ³²³. The trimmings, seeds, peels, stems, shells, pomace remaining after juice extraction, and oil cakes all provide additional support for these chemicals. Furthermore, this kind of waste is a vital source of several nutrients ³²⁴. Minerals, fibers, proteins, lipids, carbs, etc. The different safe bioactive substances found in trash include:

Phenolic Compound

As is more apparent in mango peels and seeds than pulp, the waste that results from the limited processing of finished products. Fruits and vegetables are thought to be dependent on their phenolics for both their sensory and nutritional profiles. Because of their ability to suppress free radicals, phenolic compounds have their fundamental structure, one or more hydroxyl groups and one or more aromatic rings are known to have some kind of antioxidant ¹⁹³. They provide essential functions in the growth and reproduction of the plant, take part in defense mechanisms against infections, parasites, and ultraviolet (UV) radiation, and give plants additional color. Furthermore, phenolic chemicals included in food may provide other health advantages, such as a lower chance of developing chronic illnesses ¹⁹⁴. Prior research has also demonstrated that, in comparison to edible tissue, the peel and seed sections have a high concentration of phytochemical substances. In comparison to the pulp of the same fruits, lemon, orange, and grapefruit peels contain 15% more total phenolic chemicals ¹⁹⁵. Similarly, the amount of total phenolic compounds in peach, apple, and pear peels and nectarines with yellow and white flesh is

double that of their fruit pulp. The edible pulp section of bananas has 232 mg of phenolic chemicals per 100 g of dry weight, or about 25% of the peel portion, in contrast, pomegranate pulp has 24.4 mg/g of phenolic compounds, and pomegranate peels have 249.4 mg/g ^{196,197}. It is interesting to note that the amount of total phenolic compounds in the seeds of several fruits- including avocados, jackfruit, longans and mangoes – was substantially higher than the amount that could be eaten ¹⁹⁸. Tomato peels and seeds contain more phenolic chemicals than tomato pulp. Twelve tomato genotypes were specifically studied for their phenolic component content. The results indicated that the fruit's meat, which ranged from 9.2 to 27.0g, contained more total phenolics and flavonoids per 100g than the peel, which contained 10.4 to 40.0mg/100g of these components ¹⁹⁹. When compared to pulp and seeds, the peel of some tomato cultivars contain reasonable amounts of flavonoids, ascorbic acid, and lycopene pigment in addition to phenolic components ²⁰⁰. Remarkably, the phenolic content of fruit and vegetable processing waste is ten times higher than that of pulp. These byproducts might be valued for their potential to provide phytochemicals beneficial to human health. Fruit and vegetable waste is categorized in the following booming order based on the richness of phenolic content: Peels from potatoes, watermelons, cucumbers, tomatoes, and olive leaves ²⁰¹. Additionally, date seeds are a prime source of phenolic compounds and antioxidants ²⁰². With the exception of olive oil, date seed oil has more phenolic compounds than almost any other food oil ²⁰³. Cucumber, squash, bitter melon, bottle gourd, and indian round gourd seed waste extracts have been found to be highly effective against a range of microbes, including *Escherichia coli*, *Fusarium oxysporium*, *Serratia marcescens*, *Streptococcus thermophilus*, and *Trichoderma reesei* ³²⁵. This may

be of their high phenolic content. Perhaps due to their high phenolic content, the seed waste extracts of cucumber, squash, bitter melon, bottle gourd, and Indian round gourd have been found to be incredibly effective against a variety of microbes, including *Escherichia coli*, *Fusarium oxysporium*, *Serratia marcescens*, *Streptococcus thermophilus*, and *Trichoderma reesei*. Peel and seed leftovers, or around half of the total fruit, are a major waste product of the citrus industry ^{204,205}. When compared to the edible portion, this waste contains phenolic chemicals in the highest concentration ¹⁹³. The peels of other fruits, such as pears, apples, and peaches, have also been reported to have higher quantities of phenolics than the edible portions ²⁰⁶. According to a report, banana pulp only contains 25% of the phenolic chemicals present in double that of their fruit pulp. The edible pulp section of bananas has 232 mg of phenolic chemicals per 100 g of dry weight, or about 25% of the peel portion, which is ¹⁹⁶. In a comparative analysis, pomegranate peels exhibit a concentration of 249.4 mg/g of phenolic compounds, whereas pomegranate pulp demonstrates a significantly lower concentration of 24.4 mg/g ¹⁹⁷. It is significant to highlight that the aggregate concentration of phenolic compounds present within the seeds of various fruits, including avocados, jackfruit, longans, and mangoes, was markedly superior to that of the consumable portions. ¹⁹⁸. Tomato peels and seeds contain more phenolic chemicals than tomato pulp. Twelve tomato genotypes were specifically studied for their phenolic component content. The findings showed that the quantities of these compounds were lower in the flesh, ranging from 9.2 to 27.0 mg/100 g, than in the peel section, which was 10.4 to 40.0 mg/100 g ¹⁹⁹. In conjunction with phenolic constituents, the epidermis of specific tomato cultivars exhibits substantial concentrations of flavonoids, ascorbic acid, and lycopene pigment

in contrast to the pulp and seeds ²⁰⁰. Remarkably, the phenolic content of fruit and vegetable processing waste is ten times higher than that of pulp. These byproducts might be valued for their potential to provide phytochemicals beneficial to human health. Fruit and vegetable waste is categorized in the following booming order based on the richness of phenolic content: Peels from potatoes, watermelons, cucumbers, tomatoes, and olive leaves ²⁰¹. Additionally, date seeds are a prime source of phenolic compounds and antioxidants ²⁰². With the exception of olive oil, date seed oil has more phenolic compounds than almost any other food oil ²⁰³. Peel and seed leftovers, or around half of the total fruit, are a major waste product of the citrus industry ^{204,205}. When compared to the edible portion, this waste contains phenolic chemicals in the highest concentration ¹⁹³. The peels of other fruits, such as pears, apples, and peaches, have also been reported to have higher quantities of phenolics than the edible portions ²⁰⁶. According to a report, banana pulp only contains 25% of the phenolic chemicals present in These foods may have a similar appearance to foods that are sold in stores, but throughout the production process, ingredients with proven health benefits were added, and they were created to specifically suit the nutritional needs of the target market. This can be accomplished by adding more bioactive substances to the diet that have previously been linked to positive health outcomes. Some instances of these encompass omega-3 fatty acids, vitamins A, C, and E, the minerals zinc and selenium, pro- and pre-biotics, antioxidants (such as coenzyme Q10, polyphenols, anthocyanidins, flavonoids, carotene, and lycopene), essential amino acids, and polysaccharides, among others²¹⁰. Many naturally occurring substances included in the majority of fruits, vegetables, grains, fish, dairy, and meat products, if not all of them provide benefits beyond simple nutrition ²¹¹. Soybeans'

saponins, salmon's omega-3 fatty acids, and tomatoes' lycopene are a few examples. Studies have even shown that tea and chocolate have functional qualities, or qualities beyond than just providing the usual nutrients ²¹². Growing interest in the relationship between nutrition, food ingredients, and health has led to the development of functional foods ³²⁶. Although eating well can significantly improve health and wellbeing, time-pressed customers might not have access to the best diet. Conveniently supplied components that enhance health can be found in functional meals ²¹³. The market for functional foods was launched for a number of reasons. First, people are aware of the possible advantages of nutrition in lowering the chance of illness ³²⁷. Perhaps as a result of their aging average, consumers are growing more interested in the connections between food and quality of life despite the inconsistent information they have been given. A recent survey carried out in the United States revealed that 95% of respondents thought food might enhance health in ways other than only supplying nutrients ²¹². The majority of those surveyed expressed a desire to find out more about foods having these practical uses. Both a general increase in interest in the field of preventive health and more education may share some of the blame.

Secondly, regulatory agencies are becoming more aware of and in favor of functional foods' advantages for public health. Consequently, sophisticated legal frameworks have been established in various countries, including the United States, where the Food and Drug Administration (FDA) authorizes health claims for approximately 15 distinct categories of food products, as well as in Japan, where the FOSHU (Foods for Specialized Health Use) legislation permits the marketing of over 200 functional food items.^{213,214}. Third, governments thinking about regulating functional foods are

increasingly aware of the products' financial potential when included in public health preventative programs; nevertheless, the potential cost savings have not yet been assessed. Although methods have been created for the systematic examination of the data that currently links functional meals to physiological systems that influence disease risk, the degree of process robustness differs greatly across national boundaries. A team of impartial scientists is now assembled by the FDA to compile and evaluate all pertinent clinical evidence for every submission of a health claim. The development of this comprehensive assessment process has improved the validity of health claims, which has spurred the market for functional foods to arise.

An overview of the features of functional food in various organizations is provided in Table 2.1, as seen below²¹⁶.

Table 2.1 shows an overview of the attributes associated with functional foods within various organizations as illustrated below ²¹⁶.

The Specialty of Functional Food	Description	Examples
Improved commodities	Foods that has been supplemented with new minerals or ingredients that are not ordinarily found in that food	Prebiotics, prebotics and plant sterol esters margarine
Modified and Unmodified products	Modifieed foods that have had dangerous chemicals, eliminated, decreased, replaced with a	Modified in meat and ice cream,fisbre acts as lipid or a reliver in

	chemical that have positive benefits. Unmodified foods that have extremely high levels of minerals or elements	unmodified fish products(Lcn-3 PUFA)
Enhanced Products	Foods that have had one constituent organically boosted through unique producing circumstances, food that have a new composition foods that have genetically changed, or foods that have been transformed in various ways	Eggs with a higher omega-3 concentration as a result of a change in chicken feed.
Fortified Products	Food that has been supplemented with extra nutrients	Vitamin c fortified fruit juice

Functional foods are divided into a number of categories.

An evident conclusion of research and advancement in the food product industry is the knowledge that the results of this study support "assertions," which will be translated into communications to users. Moreover, claims are essential to the production of functional foods, and two categories of claims Type A and Type B are particularly significant ²¹⁸.
Type A: Advantages for enhanced performance and improved statement (type A) makes mention to the positive correlation between specific physical tasks and a healthy eating

pattern, but it does not even suggest a link between the two and a lower risk of sickness. Preventing oxidative stress is one way that antioxidants are used ²¹⁹. Type B: Requests for a decreased risk of illness: A claim for disease risk reduction (type B) describes how consuming one or more of a set of food items or dietary components may lessen the likelihood of getting sick. One example of these claims is the reduction of the risk of cancer or cardiovascular disease. Functional food may or may not lower the risk depending on the disease, but proving such benefits has proven to be a difficult task that may require extensive testing based on solid hypotheses supported by respectable knowledge of the mechanisms of the impact to be predicted ²²⁰. Individuals now participating in clinical trials to develop new medications will need to provide evidence of their impact assertions about people. Clearly, "healthy people" or "ostensibly healthy people" make up the majority of this nutrient based on the researchers' key populations. For these individuals, the "usual" (ideally stable) diet will be modified in order to assert a (statically significant, but more pertinently, biologically significant) change in criteria reflective of a state of "excellent health." In the vast majority of cases, these paradigm food iseters/ (bio) markers were being found and, more significantly, verified ²²¹.

2.4. Functional foods and its scientific expansion

It has been demonstrated that the composition and structure of a meal, usually referred to as the feed solution, affect how easily minerals may be absorbed by the body ²²². Numerous studies investigating the creation of flexible meal plans have found that there can be multiplicative, complementary, or negating interactions between micronutrients and non-nutrients in the food matrix. For example, vitamin C increases the antioxidant properties of carotenoid molecules and revitalizes vitamin E. Additionally, in

vitro research has demonstrated that vitamin E and flavonoids, a subclass of phenolic phytochemicals, cooperate to prevent low-density lipoprotein oxidation. The correlation coefficients of nutritional and non-nutritional components must always be fully explained in order to create functional meals that have the best chance of improving people's health in a synergistic fashion, given the differing correlations between these types of components ²²³.

2.5 Valorization

Food waste (FW, dry or wet) is produced in large quantities by the food industry, and this is garnering attention due to its effects on the environment, the economy, and the growing concerns about food arising from the world's population growth, demographic shifts, and the impact of climate change on food production ^{224,225}. It's difficult to feed people recovered food made from leftovers and waste behavior. Additionally, food rescue is very costly. The food waste disposal model in use today is not founded on methods that are economically sustainable. Additionally, the type of food determines how much food is wasted or lost. As an illustration, when it comes to perishable food, such fruits and vegetables, there is more loss and waste. Furthermore, the recovery of byproducts is a prerequisite for the manufacture of FW. For instance, in the US, the carcass yield for processing cattle meat is about 40%; this comprises roughly 10%, 40%, and 5% of skins, bone, and paunch, yet, a large portion of these are regarded as trash. Regarding poultry, the reported carcass yield is 40% for deboned birds and 80% for entire birds ²²⁷. On the other hand, fish is said to have a carcass yield of 40–50%. A 25-30% recovery rate is achieved by sweet corn, processed tomatoes, potatoes, peppers, cereals, and soy; the remaining 90% is used for animal feed ²²⁷. Food loss and waste were 34%, 13%, and 4%,

respectively, at Canada's primary processing, secondary processing (additional processing), and distribution stages. About 30–35% of whole fruits are produced by the fruit businesses as FW ^{228,229}. On the other hand, the reported FW for durian was 60%. 58% of the food supply in Canada is wasted or lost. On the other hand, it is possible to recover thirty percent of food waste, which might then be distributed to various communities throughout the nation. In the event that food recovery is not included, the final FW would be less than the stated ²²⁷. 63% of foods that should have been consumed were thrown away by Canadian consumers in 2017, and about \$49.5 billion of FW was preventable ^{230,231}. The percentages of preventable food loss and waste in 2019 were 6%, 23%, 20%, 5%, 12%, 13%, and 21%, respectively, in retail stores, hotels, restaurants, manufacturing, processing, distribution, and consumer levels. Nonetheless, the food waste in the United Kingdom was primarily the result of the manufacturing, processing, distribution, and consumption sectors, which made up 28%, 17%, 9%, and 46% of the total, respectively on average, fruits and vegetables made up more than 45% of all food worldwide (Figure 1) ²¹². FW that cannot be avoided, such as fruit peels, skins, and twigs, typically contains more bioactive chemicals than the edible parts ^{234,235}.

Furthermore, food processing waste has been found to be high in protein, fat, and carbohydrate, showing potential for valorization (the process of turning FW into products with added value) in the production of chemicals, prebiotics, animal feed, and cosmetics ²³⁶⁻²³⁸. It may have a significant impact in lessening issues related to FW ²³⁹.

Figure 2.1 Part of several types of food waste worldwide. [In many jurisdictions, fruits and vegetables make up the majority of the food waste (FW), with grains, milk, meat, roots and tubers, and other foods coming in second. However, the food, the phases of processing and the food supply networks, and the jurisdictions all affect the formation of FW. A Canadian household wastes \$1766.0 on food every year on average, out of which are wasted ²⁴⁰. Each year, 35.5 million tons of food are wasted or lost, resulting in 56.5 million tonnes of greenhouse gas emissions (CO₂ equivalent) in Canada ^{241,230}. About \$100 billion is spent on FW annually, of which \$49 billion is disposed of in landfills or composted, having an impact on the environment, the economy, and society ^{232,242}. Nonetheless, 13.1 million tonnes of food waste (FW) were produced in the UK, which led to 27.0 million tons of greenhouse gas emissions. However, food waste (FW) in the United Kingdom (UK) was 13.1 million tonnes, resulting in 27.0 million tonnes of greenhouse gas emissions ²³³. It was noted that vegetables and cereals produced 31% and 28% of the overall fisheries yield (FW), respectively. Meat and fish, on the other hand, contributed just 10% of the total FW, but were the main sources of emissions. Initiatives for FW prevention and recovery have been found to have an annual net economic worth of over \$10 billion in the United States²⁴³. Given its importance to the environment, the economy, society, society, and health, FW and loss is included among the ten circular economies. A circular economy eliminates trash while preserving its highest value indicator by restoring or renewing things through industrial processes and economic activity ²⁴⁴. Valuing the enormous quantity of FW can lower GHG emissions and have positive economic effects ²⁴⁵. The life cycle inventory increases with increasing food loss ²⁴⁶. It is noteworthy to remember that over \$1 trillion and 26×10^9

GJ of energy are squandered annually worldwide ²⁴⁷. Consequently, in order to decrease food, it is crucial to both decrease and valorize FW ^{248,249}. Energy insecurity, reduce greenhouse gas emissions from food waste, and boost the food industries and farms profitability. Furthermore, it is stated that the sustainability of food chains will be enhanced by the effective valuation of FW ²⁵⁰. It was passed to handle the growing amount of garbage produced and to advance the circular economy, which includes organic waste ^{151,251}.

FW can be valorized in a number of ways, depending on their qualities, to create chemicals (biofertilizer, biocarbon, activated carbon, graphene, additives, volatile acids, etc.) for a range of applications, solid, liquid fuels, heat and power, or biomaterials. For instance, processed FW was utilized as a filler material in the production of biocomposite, bioplastics, and heat and power generation in the process of valorization ^{229,252,253-255}. Nevertheless, bench casting has also been used to create a biodegradable composite film using leftovers from the preparation of carrots for use in food packaging ²⁵⁶. FW remain a resource in the circular food economy, it must be handled as it carries a significant environmental and socioeconomic impact. In order to assess the advantages of circular economy and bioeconomy concepts over the current management methods, the policy initiatives in FW management have been compiled ²⁵⁷. While the FW valuation procedure for biomaterials, biocomposite, biofuels, or animal feed has been assembled by multiple authors ²⁵⁸⁻²⁶⁰.

2.5.1 Hunger and Food Waste

Every year, tonnes of food are lost or squandered worldwide ²⁶¹⁻²⁶³. The industrialized world (population 1.4 billion) and the developing world (population 6.2 billion) throw away a combined amount of tonnes of edible food^{255,264}. There are still 690–829 million hungry people in the world ²⁶⁵⁻²⁶⁷. A nutritious diet is out of reach for almost 3 billion people ^{265,266}. 38 million Americans experience food insecurity, and have gone without food at some point ²⁶⁹.

2.5.2 Food Waste Valorization

Food waste, which includes both edible and inedible food, is produced at three distinct stages of the food life cycle: preharvest, postharvest, and industrial. The makeup of food waste also differs greatly throughout various food waste sources and jurisdictions ²⁷⁰. Generally speaking, food waste originating from animals is higher in energy than food waste originating from watery plants, like fruits and vegetables ²⁷¹. Therefore, when producing value-added end products for various applications, the selection of technologies for food waste valorization depends on the moisture content and makeup of the waste in order to prevent energy-intensive processes. Foodborne illness (FW) usually occurs at every point in the food supply chain, including the industrial (Postharvest, processing, and distribution), retail, residential, and food services sectors, due to contamination or decreased quality ²⁷². It produces FW that is both edible and inedible. Food waste (FW) is defined as food that is thrown away or portions of food that are not edible. Lack of markets, inadequate infrastructure, inadequate technology, inadequate skills, and inadequate management and logistics all contribute to food loss ²⁷³. The sort of food, economic advancements, consumption, marketing, and purchasing behaviors all

influence the FW generation ^{274,275}. Furthermore, the sociodemographic composition of homes also has a significant impact on the FW generation ²⁷⁶⁻²⁷⁸. For instance, among young consumers, bread is the food item that is wasted the most ^{275,279}.

The annual household level FW generation in the chosen nations is ^{266,280}, as shown in Fig. 2.2. In 2019, the household level created 569 million tonnes of fresh water, contributing to the 931 million tonnes of fresh water generated globally. Meanwhile, people are undernourished ^{265, 266}. The retail and food service industries contributed 118 million tonnes and 244 million tonnes, respectively, to the total FW ²⁶⁶. The main source of FW in the post-consumer stages is food services. For instance, buffet services waste 50% of the food that is on display ²⁸¹. Just 10-15% of leftover food can be safely donated due to food safety rules ²⁸². Thus, the efficient and creative use of FW could accomplish two goals at once, FW which is normally disposed of in landfills, might be diverted, and value-added products could be produced that the food industry or other sectors could use. This would lower the cost of waste management for the food industry and reduce greenhouse gas (GHG) emissions.

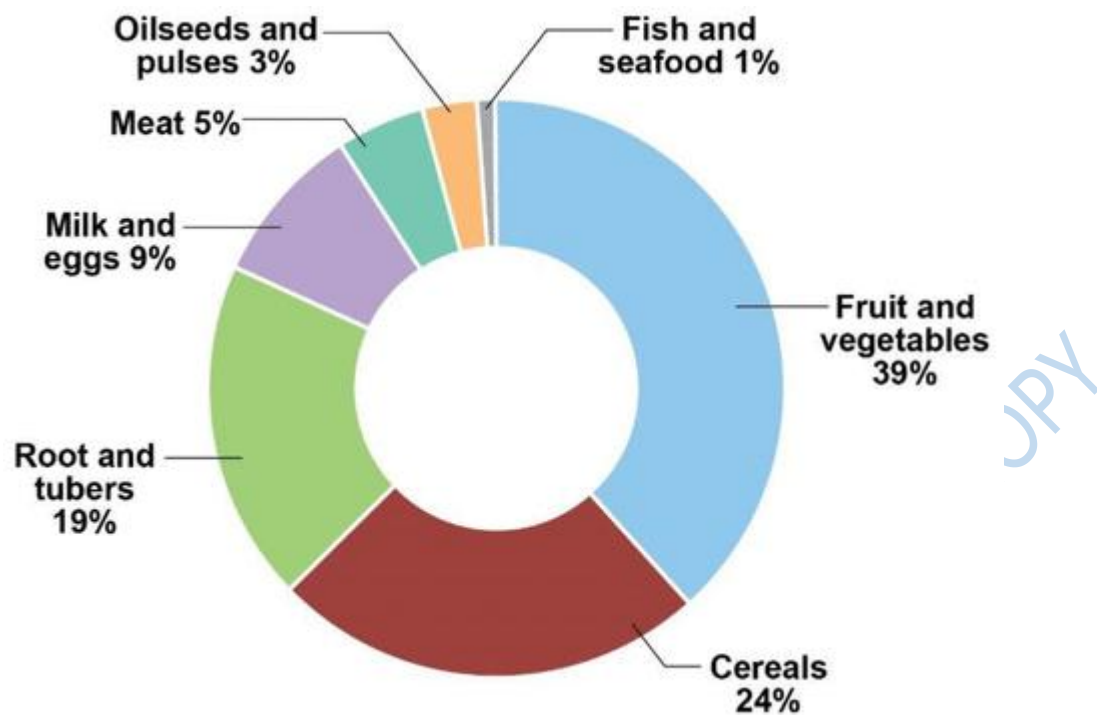


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Food waste, which includes both edible and inedible food, is produced at three distinct stages of the food life cycle: preharvest, postharvest, and industrial. The makeup of food waste also differs greatly throughout various food waste sources and jurisdictions²⁷⁰. Generally speaking, food waste originating from animals is higher in energy than food waste originating from watery plants, like fruits and vegetables²⁷¹. Therefore, when producing value-added end products for various applications, the selection of technologies for food waste valorization depends on the moisture content and makeup of the waste in order to prevent energy-intensive processes. Foodborne illness (FW) usually

occurs at every point in the food supply chain, including the industrial (Postharvest, processing, and distribution), retail, residential, and food services sectors, due to contamination or decreased quality ²⁷². It produces FW that is both edible and inedible. Food waste (FW) is defined as food that is thrown away or portions of food that are not edible. Lack of markets, inadequate infrastructure, inadequate technology, inadequate skills, and inadequate management and logistics all contribute to food loss ²⁷³. The sort of food, economic advancements, consumption, marketing, and purchasing behaviors all influence the FW generation ^{274,275}. Furthermore, the sociodemographic composition of homes also has a significant impact on the FW generation ²⁷⁶⁻²⁷⁸. For instance, among young consumers, bread is the food item that is wasted the most ^{275,279}.

The annual household level FW generation in the chosen nations is ^{266,280}, as shown in Fig. 2.2. In 2019, the household level created 569 million tonnes of fresh water, contributing to the 931 million tonnes of fresh water generated globally. Meanwhile, people are undernourished ^{265, 266}. The retail and food service industries contributed 118 million tonnes and 244 million tonnes, respectively, to the total FW ²⁶⁶. The main source of FW in the post-consumer stages is food services. For instance, buffet services waste 50% of the food that is on display ²⁸¹. Just 10-15% of leftover food can be safely donated due to food safety rules ²⁸². Thus, the efficient and creative use of FW could accomplish two goals at once, FW which is normally disposed of in landfills, might be diverted, and value-added products could be produced that the food industry or other sectors could use. This would lower the cost of waste management for the food industry and reduce greenhouse gas (GHG) emissions.

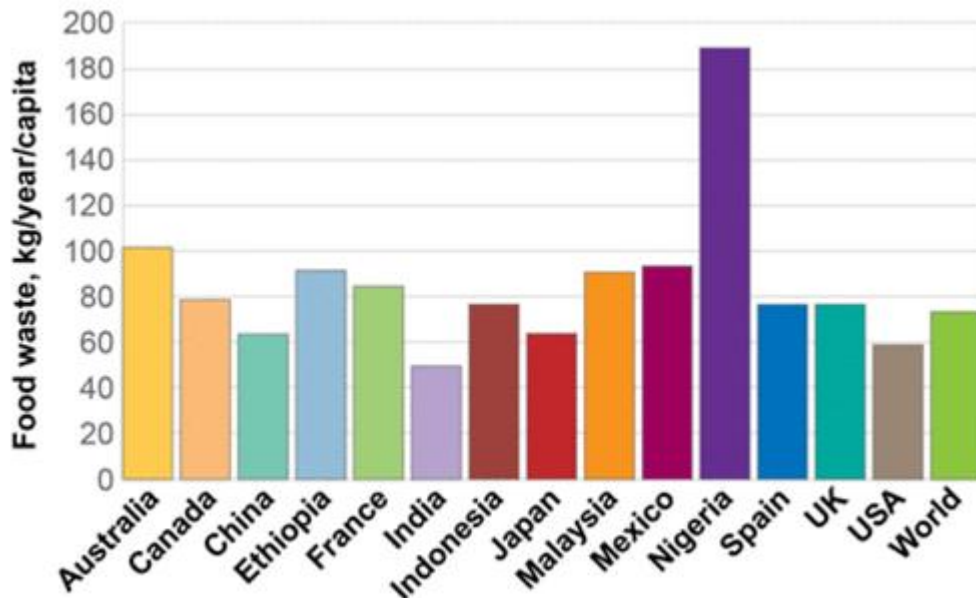


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2.5.5 Measures to Reduce Food Waste

Huge efforts are being made to reduce food waste (FW), including modernizing storage systems, increasing process efficiency, improving transportation and packaging, developing foods that can withstand stress, particularly fruits and vegetables to lengthen their shelf life, and making regulatory adjustments ³²⁸. Increased shelf life can lower FW in households and retail settings. Active and intelligent packaging has been developed in tandem with the development of digital tools (traceability, intelligent tools, and sensors/indicators for temperature, leak, freshness, and pH) ³²⁹. Along with the development of digital tools (traceability, intelligent tools, and sensors/indicators for temperature, leak, freshness, and pH), active and intelligent packaging has also been developed. The advanced technological instruments are recognized for their efficacy in reducing food deterioration, as they assess numerous quality parameters and convey the quality condition of products to the relevant stakeholders engaged in food supply chains (ranging from producers to consumers) ^{283,284}. For instance, displaying the gas concentrations, gas sensors can indicate the state of spoiling ²⁸⁴. Thus, using intelligent packaging in food systems can be very helpful in minimizing spoiling, warning customers about food quality and safety issues, and lowering FW ^{272,283,285,286,287}. Furthermore, a more durable method of lowering FW and The mitigation of environmental impacts could potentially be achieved through the synthesis of biodegradable polymers derived from food waste, which could subsequently be employed in the domain of sustainable food packaging. ²⁸⁸. Several applications have also been created to prevent food waste and its negative effects on the environment by directing extra food to food banks or nearby communities. In Canada, for instance,

businesses with excess food can connect with about 2300 social groups through the Second Harvest Food Rescue App, which distributes excess food to lower FW ²⁸⁹. Thoughtful purchases and implementing sufficient storage, consumers can significantly contribute to reducing FW at the household level ^{290,291}. Furthermore, it is widely recognized that the segregation of organic waste at its point of origin constitutes an effective strategy for redirecting a portion of the discarded food for utilization as animal feed or for redistribution, thereby contributing to the reduction of overall food waste generation ³³⁰. Additionally, a number of policy actions have been implemented to remove FW from the food chain. For instance, in order to safeguard food donors and lower FW, Canada developed legislation and policy around food donations ²⁹². Instead of disposing of excess nutritious food in landfills, restaurants and supermarket stores in the United States of America should donate it to nonprofits that fight hunger²⁹³. Additionally, by 2030, the UN asked nations to cut FW in half across the food chain ²⁹⁴. Valorization of that waste or undervalued product is the process of converting FW, byproducts, or undervalued biomass into valued products and their useful applications. Diverse conversion methodologies are employed to generate value-added goods tailored to distinct uses. A few of the products, conversion methods, and possible uses for the valuation process are shown in Figure 3. FW typically has a high moisture content, which helps it in some conversion processes like hydrolysis, anaerobic digestion (AD), fermentation, hydrothermal carbonization (HTC), etc. However, FW occasionally requires size reduction or pretreatment (ultrasound, microwave, pulsed electric field, etc.) in order to improve the conversion process and extract additional value-added products ³²⁸. Carbohydrates, proteins, minerals, lipids, water, and natural acids are all

abundant in FW ²⁹⁵⁻²⁹⁷.It therefore presents the possibility of fermentative compounds ^{295,297}.

In addition to bioenergy, FW has been used to create a variety of value-added products, the yield of which is influenced by the constituent parts of FW. Better quality products are produced by pulsed electric field pretreatment, which is superior ^{298,299}. Utilizing polymeric matrixes in conjunction with dried and crushed food waste/byproducts such wheat bran, potato fiber, and pea fiber, a biocomposite for environmentally friendly pots, containers, non-woven tissues, and films was created ³⁰⁰. The several extraction techniques that have been applied under ideal circumstances to obtain the highest yields of phenolic compounds from distinct potato peels; these yields varied according to the potatoe cultivars and extraction methods, ranging from 10.3 to 593.3 mg/100 g (dry basis) ³⁰¹. Moreover, it has been observed that organic compounds that have been isolated from different FW, particularly from the leftovers of fruits and vegetables, can be revalorized and utilized to prevent corrosion in corrosive conditions ³⁰².

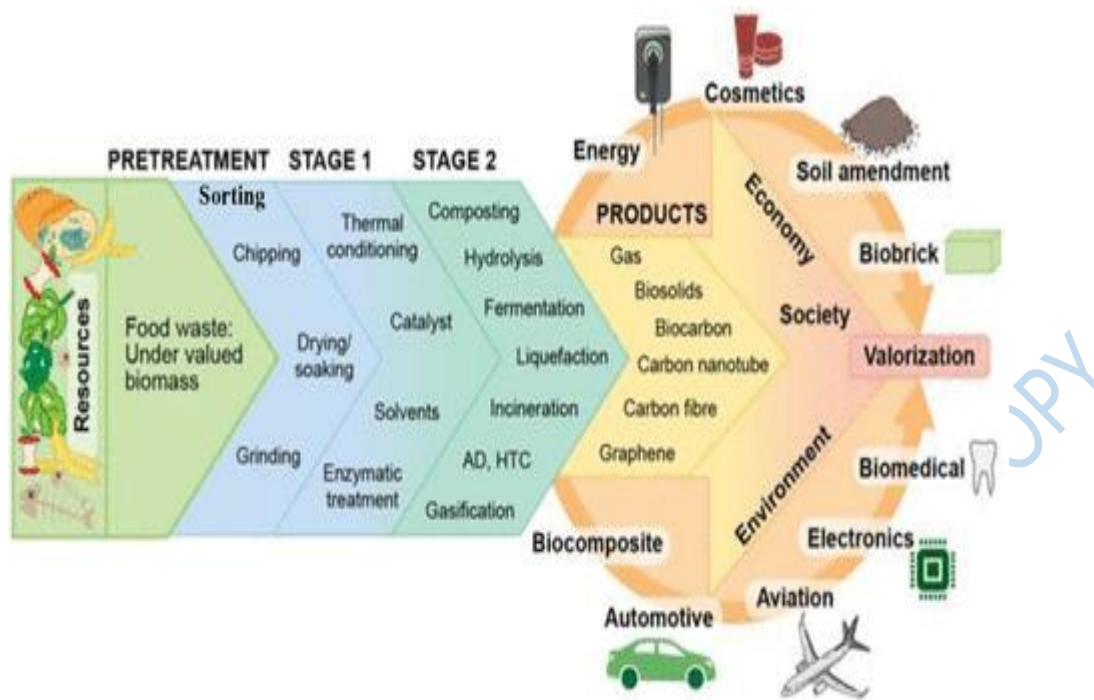


Figure 2.3: Anaerobic digestion (AD) and hydrothermal carbonization (HTC) processes, products, and uses of food waste valorization. The possible sources of food waste, value-added goods made from food waste, and their uses in many fields are depicted in this picture. These factors can have a significant impact on how long food waste valorization procedures can last. The stages 1 and/or 2 of the valorization process, the pretreatments, and the kinds of FW all affect the product yields ³⁰¹.

Utilizing Products Derived from Food Waste or Treated Food Waste

There have been numerous reports of the use of biochar and bicarbon in a variety of applications, such as cement mortar, soil amendments for water purification and crop growth enhancement, and catalytic materials for the catalytic conversion process ³⁰⁴⁻³⁰⁹. Utilized as an addition in FW's AD to increase biogas production and for energy storage ^{258,303,310}. Examples include a composite made of biochar that was used to remove contaminants from water ^{311, 312}. Additionally, biochar is added to the soil for growing

wheat, as evidenced by improved crop growth ³⁰⁶. Additionally, carbon that has been purified from tea waste has improved electrochemical properties and a higher capacitance, making it suitable for use in porous carbon-based electrical devices ³¹⁰. Nonetheless, format, which has undergone hydrothermal conversion, is a great hydrogen carrier that can be utilized as a fuel cell material ³⁰⁵. Value-added goods, including anthocyanins and antioxidant compounds, have a variety of industrial uses, including in the food industry. Anthocyanins, for instance, are sensitive to storage temperature and can be employed as natural pigments in French meringue ^{313, 314}. There have been reports on the use of colorants made from coffee waste in the creation of bioenergy and dental health ³¹⁵.

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Chapter Three

3.0 Materials and Method

The material used in this study was avocado (*Persea Americana*) seed of the Fuerte variety, This experiment was carried out at the laboratory of Human Nutrition and Dietetics, Lead City University, Ibadan.

3.1 Materials Procurement

Mature Avocado fruits in season were harvested at Forestry Research Institute of Nigeria (FRIN) Ibadan, Oyo State.

3.2 Preparation of Avocado Seed Powder

Avocado seeds were cleaned, removed from the pulp and the resulting seeds were subjected to oven drying. The material was then blended into a smooth powdery form using a grinder with grinding knives and then passed through a sieve to obtain 0.5mm particles. Then it was stored in a clean screw cap bottles for subsequent analysis.

The resulting oven dried avocado seed powder was used to prepare bread at 0%, 5%, 10% inclusion levels.

3.3 Proximate Analysis

Analysis of ash, crude fat, crude protein, moisture, carbohydrate, crude fibre were determined using AOAC method..

3.4 Determination of Total Phenol

The following were used;

1. Folin Ciocalteu reagent (10% v/v): 10ml of FolinCiocalteu reagen was taken (2N) and diluted with 90ml distilled water Transferred into brown bottle and stored in a refrigerator (4°C).
2. Sodium carbonate 7.5% 7.5 g sodium carbonate (x10 H₂O) was weighed, dissolve it in 60 ml distilled water and make up to 100 ml with distilled water.
3. Insoluble polyvinyl pyrrolidone (polyvinyl polypyrrolidone, PVPP): Commercially available from Sigma, P 6755.
4. Standard tannic acid solution (0.1 mg/ml): Dissolve 10 mg tannic acid (TA) obtained from Merck in 100 ml distilled water and (always use a freshly prepared solution).

Extraction;

1. Weighed 250mg of sample into 25ml beaker
2. Added 25ml 70% aqueous acetone and suspended the beaker into ultrasonic water bath for 20mins at room temp.
3. Transferred the content into the centrifuge tube and centrifuge for 10min @ 3000rpm at 40C(if refrigerated centrifuge is not available cool the content by keeping the centrifuge in ice)
4. Collected the supernatant
5. Transferred the pellet left in centrifuge tube to beaker using two portions of 5ml each of 70% aqueous acetone & subject the content again to ultrasonic treatment for 20min.
6. Collected the supernatant as described above. Once the particle size of the ground plant materials was very fine & recovery of total phenol is <5% of the first supernatant the second extraction step can be omitted.

Analysis of phenol;

Took (500ml) of the extract in a 10ml test tube, Added 500ul folincioalteu reagent, then 1ml sodium carbonate solution made up the volume with distilled water, then votex the tubes.

Recorded the absorbance at 725nm after 40min. Calculated the amount of total phenol as tannic acid equivalent.

Prepared the standard by taking 0, 20,40, 60, 80, 100 ml in to 10ml test tube add 0.23ul folin ciocalteu reagent, then 1.25ml sodium carbonate solution Make up the volume with distilled water, votex the tube and read the absorbance as above

Calculation

$$\text{Phenol \%} = \frac{C \times V \times D.F}{W \times 10}$$

Where;

C = concentration phosphorus in measured solution (mg/litre),

V = volume of solution (in litres, i.e. 0.025 L),

DF = dilution factor (normally, i.e. 1),

W = weight of the sample (g), and

10 = factor to convert g/kg to %.

3.5 Determination of Scavenging Activity of DPPH

Radical scavenging hydrate DPPH antioxidant activity of the extract was measured in terms of hydrogen donating or radical scavenging ability using the stable free radical DPPH. Determination of DPPH radicals scavenging activity was estimated with the method used by Kato. 1mM solution of DPPH in ethanol and also 1mg/ ml sample in ethanol was prepared at room temperature for 30minute and was kept in a brown volumetric dark flask in order to avoid degradation. 1.5ml of the extract solution was added to 1.5 ml of DPPH. The absorbance was measured at 517 m against the corresponding blank. 1mg/ml of Ascorbic acid solution was use as controlwhich is prepared by taking 1.5ml ethanol with 1.5ml of DPPH which was measured at the same wavelength on a UV-VIS spectrophotometer. The antioxidant activity (AA%) percentage was calculated using the formula

$$AA\% = \frac{A_{\text{Control}} - A_{\text{Sample}}}{A_{\text{Control}}} \times 100$$

Where:

A_{Control} = absorbance of a DPPH solution without sample;

A_{Sample} = absorbance of the sample mixed with 0.02 mg/mL DPPH solution.

3.6 FRAP (Ferric reducing antioxidant properties)

sample was taken at 10ml and was mixed dissolved in the 2.5 ml taken from the mixture of 200 mmol/l phosphate buffer (pH 6.6) and 2.5 ml of 1% potassium ferricyanide, which is then incubated at 50 °C for 20 minutes. Thereafter, 2.5 ml of 10% trichloroacetic acid was added to the incubated sample while the tubes were later centrifuged at 10,000 rpm for 10mins. 5ml of supernatant was then mixed with 5.0 ml of distilled water and 1 ml of 0.1% ferric chloride, followed by reading the absorbance at the wavelength of 700 nm. Meanwhile, the same procedure was done using ascorbic acid as the positive control.

$$\text{FRAB } \text{Fe}^{2+} \text{ mM/kg} = \frac{C \times V}{W \times 55.85}$$

Where;

C=conc. In mg/l

W=weight of sample

55.85 = molar mass of iron

3.7 Determination of Loose and Packed Bulk Density

Flour of 2g was weighed into a 25ml measuring cylinder and volume V_1 of the flour was noted. The flour particles inside the cylinder was tapped several times for 10min till a constant volume V_2 was obtained.

Loose Bulk Density (LBD) was obtained using the formula:

Weight of sample

Volume V_1

Packed Bulk Density (PBD) was obtained using the formula:

Weight of Sample

Volume V_2

3.8 Determination of Water Absorption Capacity (WAC)

Flour of 2g was weighed into a 250 ml beaker, 25ml of distilled water was added and stirred uniformly with a glass rod for 30minutes. After the stirring, the dispersions were transferred into centrifuge tubes and the beakers were rinsed with 10ml of distilled water. The samples were centrifuged at 3000rpm for 15min. The supernatant was decanted and determined for solids contents. Water Absorption Capacity was determined using the formula:

$$\frac{\text{Weight of Flour Sample} - \text{Weight of Sediment}}{\text{Weight of Sample}} \times 100$$

Dispersibility or Reconstitution Index

10g of sample was weighed into a 100ml measuring cylinder. 100ml of distilled water added, stirred vigorously and allowed to settle for 3hrs. The volume of settled particles is recorded and subtracted from 100 to give % Dispersibility. The dispersibility of a flour mix in water indicates its reconstitutability. The higher the value the better.

Least gelation concentration

The method was followed with slight modification. Proper sample suspensions of 2, 4, 6, 8, 10, 12, 14 and 16% w/v were prepared in 10ml distilled water. The test tubes containing these suspensions were heated in a boiling water bath for 60minutes. the test-tubes were rapidly cooled to 40°C under running tap water. The least gelation concentration (%) was determined as the minimum concentration when the sample from

the inverted test tube did not fall or slip down.

Water and oil absorption capacity (WAC AND OAC)

Test procedure was applied. 5ml of distilled water or a named oil (Specific Gravity) were added to 0.5g of sample flour in 10ml graduated centrifuge tubes. The mixture was stirred with glass rod to disperse the sample in distilled water oil. After holding for a period of 30min, it was centrifuged for 30min. at 3500rpm. The excess water or oil absorbed was expressed as the percentage water or oil bound by 100g sample. The density of the oil was determined using the specific gravity bottle.

Results

$$\frac{\text{Volume of bound water or oil} \times 100}{\text{Weight of sample}}$$

$$W (\%) = \frac{\text{Volume of bound water or oil} \times 100}{\text{Weight of sample}}$$

$$\text{Density of water} = 1\text{g/ml or oil} = ? 0.88\text{g/ml}$$

$$\text{Weight of sample} = ?$$

$$\text{Initial volume of water or oil} =$$

$$\text{Final volume of water or oil} =$$

$$\text{Volume of bound water or oil} =$$

$$\% \text{ bound water or oil} =$$

3.9 Determination of Foaming capacity (FC) and(FS) stability

1g sample was whipped with 50ml of distilled water for 3min in Kenwood blender at speed 'soft' and 'max' and was poured into a 100ml graduated measuring cylinder to measure the volume.

$$\text{Foaming capacity } (\%) = \frac{\text{Volume after whipping} - \text{volume before whipping}}{\text{Volume before whipping}}$$

The foaming stability was measuring by measured the foam value after standing for intervals of 0, 5, 10, 30, 60 and 120min and so on until a stable volume was obtained. The volume is expressed as per cent of the initial foam volume. [Note: stability as per cent of the initial foam volume]

3.10 Determination of Emulsion capacity (EC)

1g of sample was made into slurry in 20ml distilled water in an Erlenmeyer flask by stirring as 1000rpm for 15min with a magnetic stirrer. 5ml of edible oil (e.g. edible Savoil oil) was added and stirring was continued for another 1 min. the system was transferred to centrifuge tube and finally centrifuge at 3500rpm until the volume of oil separated from emulsion was constant.

Result

$$\text{Emulsion capacity (\%)} = \frac{\text{Height of emulsified layer}}{\text{Height of the whole layer}} \times 100$$

Determination Emulsion stability (ES)

1g sample was blended in a kenwood blender with 50ml of distilled water for 30 seconds at high speed. Oil was added continuously from burette at the rate of 5ml per minute while blending was continued. When the nature of emulsion changed, as marked by decreasing homogeneity, oil addition was stopped. The emulsion so prepared was allowed to stand in a graduated cylinder and volume of water separated at time intervals of 0, 0.5, 1, 2, 3, 4, 5, 6, and 24 hours was noted in each case emulsion stability.

Result

$$\text{Emulsion stability (\%)} = \frac{\text{Height of the remaining emulsified layer}}{\text{Height of the whole emulsion layer in the}}$$

Determination of Swelling Power / Swelling Capacity

0.1g of sample was weighed into a weighed test tube into which 10ml of distilled water was added and heated in a water bath at temperature of 60°C for 30mins, this was continually shaken within the heating period. At the end of the test tubes was centrifuge at 1000 x g for 15mins in order to facilitate the removal of the supernatant which was carefully decanted and the weight of the starch paste taken. And swelling power was calculated as follows:

$$\text{Swelling Power} = \frac{\text{Weight of starch paste}}{\text{Weight of dry starch sample}}$$

3.11 Data Analysis

Results of each parameter for avocado seed powder was presented as mean± standard deviation. Differences in mean values for the varying levels of avocado seed powder in bread were subjected to one way analysis of variance (ANOVA) with Duncans Multiple rage test used for comparison.

3.12 Bread Making Procedure

The following procedure was carried out using the following steps

All ingredients were well labeled for easy identification and accessibility, instruments were cleaned and sanitized.

Weighed all ingredients at exact proportion need;

- i. 400g of flour
- ii. 7g of yeast
- iii. 3g of salt
- iv. 30g of powdered milk
- v. 190ml of water

vi. 30g of butter

vii. 45g of sugar

viii. Half an egg

Got 3 different large bowl labeled A, B and C because of the samples, mixed 400g of flour, 7g of yeast, 3 g of salt, 30g of powdered milk, 45g of sugar and half egg together for sample A. For sample B i used 380g of flour which is 5% ASP and for sample C I used 360g of flour for 10% ASP, mixed the ingredients together until a shaggy dough was formed, added 30g of margarine to all samples.

Turn the dough out into a neat flat surface and knead for about 15 minutes, until the dough is smooth and elastic. Placed the dough in an already greased pan which was set aside before and weighed all the 3 samples.

Covered with a damp towel to rise in a warm place for about an hour.

Pre heat the oven

Baked the bread for 20 minutes till the crust is golden brown and the bread sounds hollow when tapped on the bottom.

Removed the bread from the oven and it was left cool before weighing.



Sample A with (0% ASP)



Sample B with (10% ASP)



Sample C with (5% ASP)



Sample A with (0% ASP)



Sample B with (10% ASP)



Sample C with (5% ASP)

Endnotes

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Chapter Four

4.0 Results and Discussion of Analysis

Table 4.1 Proximate composition of Avocado Seed Powder

Moisture	Protein	Fat	Fibre	Ash	Carbohydrates
10.66±0.14	5.81±0.08	2.83±0.05	3.16±0.07	2.43±0.02	75.1±0.20

The proximate analysis of the powder derived from avocado seeds indicates that it possesses a moisture content of 10.66%, thereby ensuring that the sample retains a sufficient level of water. The protein concentration within the sample is quantified at 5.81%, signifying its prospective nutritional significance, particularly in supplying vital amino acids. The lipid content is comparatively minimal, recorded at 2.83%, which could prove beneficial for individuals pursuing a low-fat dietary regimen. Concurrently, dietary fiber, a crucial element for gastrointestinal health, constitutes 3.16% of the powder. The ash content, measured at 2.43%, signifies the aggregate mineral composition. Carbohydrates are predominant within the formulation, comprising 75.1% of the sample, thereby reflecting the considerable energy-yielding capacity of the avocado seed powder.

4.2 Total Phenolic Content and Antioxidant Activity of Avocado Seed Powder

Total Phenolic	DPPH	Ferric Reducing Antioxidant Powder
21.2±0.08	75.02±0.25	0.450±0.042

Diphenyl-2-picryl-hydrazyl radical scavenging activity; FRAP= Ferric reducing antioxidant powder

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Table 4.3 Functional Properties of Avocado Seed Powder

LBD	PBD	OAC	WAC	FC	FS	SC	EC	ES	%DIS	LGC
(g/ml)	(g/ml)	(g/100g)	(g/100g)	(%)	(%)	(g/g)	(%)	(%)		(%)
0.53±0	0.62±	118±0.3	124±0.2	21.7	12.1	13.1	32.0	19.	87.99	9.17±
.0	0.0			±0.	±0.0	±0.0	±0.0	8±0	±0.01	0.03
				04	3	2	2	.02		

LBD= loose bulk density; PBD= packed bulk density; OAC= oil absorption capacity; WAC= water absorption capacity; FC= foaming capacity; FS= foam stability; SC= swelling capacity; EC= emulsion capacity; LGC= least gelation capacity

4.1 Proximate composition of bread fortified with avocado seed powder.

Results for proximate composition of bread fortified with ASP are presented in Tables 4.2. It was observed that addition of ASP resulted in significant increase in moisture content of the bread, compared with the control ($p=0.003$). On the other hand, the inclusion of ASP at 5 and 10% significantly reduced protein and fat content ($p=0.007$ and 0.004 respectively).

Contrasting results were observed for fibre content, where 5% inclusion of ASP significantly reduced fibre compared with control, while at 10% ASP, fibre content exhibited a 25% increase in fibre beyond the control treatment ($p<0.0001$). Carbohydrate content of bread at 10% ASP was observed to be marginally higher than the control and 5% ASP ($P=0.075$).

Table 4.4 Proximate Composition of Bread Fortified with Avocado Seed Powder

	Moisture	Protein	Fat	Fibre	Ash	Carbohydrate
Bread 0% ASP	13.1a	12.3a	6.55a	2.02b	1.80b	64.3
Bread 5% ASP	13.8b	12.0b	5.48b	1.29c	2.47a	64.9
Bread 10% ASP	13.4c	11.7c	5.20b	2.53a	1.84b	65.3
SEM	.02	.03	.055	.018	.028	.11
P-value	.003	.007	.004	.000	.004	.075

a, b, c, Values in the same column with different alphabets are significantly different ($p < 0.005$). ASP: avocado seed powder; SEM: standard error of mean

4.2 Effects of Avocado Seed Powder on Antioxidant Content and Activity

The results of the effect of ASP on is shown in Table 4.4

It was observed that the addition of ASP significantly increased total phenolic content of bread at 5% and 10%, compared to the control ($p=0.000$). DPPH activity was also observed to increase significantly with the addition of ASP at 5 and 10% ($p=0.000$). However, ferric reducing antioxidant power did not differ significantly ($p=0.629$) between the treatments.

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Table 4.5 Antioxidant Activity of Bread Fortified with Avocado Seed Powder

	Total Phenolic	DPPH	FRAP
Bread 0% ASP	0.39c	57.83c	0.460
Bread 5% ASP	1.67b	62.41a	0.505
Bread 10% ASP	2.10a	61.87b	0.435
SEM	.002	0.068	0.028
P-value	0.000	0.000	0.629

a, b, c, values in the same column followed by different letters are significantly different ($p < 0.05$). ASP= avocado seed powder; SEM= standard error of mean; DPPH= Diphenyl-2-picryl-hydrazyl radical scavenging activity; FRAP= Ferric reducing antioxidant powder

4.3 Functional Properties of Bread Fortified with Avocado Seed Powder

The result of the effect of Avocado Seed Powder is shown in table 4.6, it was observed that addition of ASP significantly increased parameters of loose bulk density, packed bulk density, oil absorption capacity, water absorption capacity, foaming capacity, least gelation capacity, swelling capacity, emulsion capacity at 5% and 10% compared to the control.

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4.6 Functional Properties of Bread Fortified with Avocado Seed Powder

	LB	PBD	OA	WA	FC	FS	SC	EC	ES	%DI	LG
D	g/ml	C	C	%	%	%	%	%	%	S	C
	g/ml	g/10	g/10								%
		0	0								
Bread	0.51	0.58	96.4	115.	18.5	10.5	11.7	29.7	18.6	83.3	7.61
0%ASP	5c	8c	c	6c	b	c	c	c	b	c	c
Bread	0.51	0.59	99.3	117.	18.4	10.7	11.9	29.9	18.6	83.7	7.80
5%ASP	9b	1b	b	4b	c	b	b	b	b	b	b
Bread	0.52	0.60	102.	119.	20.2	11.1	12.9	31.7	19.5	85.8	8.83
10%ASP	2a	9a	6a	6a	a	a	a	a	a	a	a
SEM	0.00	0.00	0.07	0.07	0.00	0.01	0.00	0.01	0.00	0.00	0.00
	1	1	8	8	9	1	8	1	9	9	9
P-value	<0.0	<0.0	<0.0	<0.0	<0.0	<0.0	<0.0	<0.0	<0.0	<0.0	<0.0
	01	01	01	01	01	01	01	01	01	01	01

Values in the same column followed by different letters are significantly different ($p < 0.05$). LBD= loose bulk density; PBD= packed bulk density; OAC= oil absorption capacity; WAC= water absorption capacity; FC= foaming capacity; FS= foam stability; SC= swelling capacity; EC= emulsion capacity; LGC= least gelation capacity ASP: ES= Emulsion stability, avocado seed powder; SEM: standard error or mean.

4.4 Sensory Attributes of Bread Fortified with Different Levels of Avocado Seed Powder

Table 4.8 indicated people's choices and their best preferences in choosing between the control, 5 % and 10% ASP. Nine parameters was evaluated, loaf appearance of the control had higher likeness compared to the 5% and 10%.

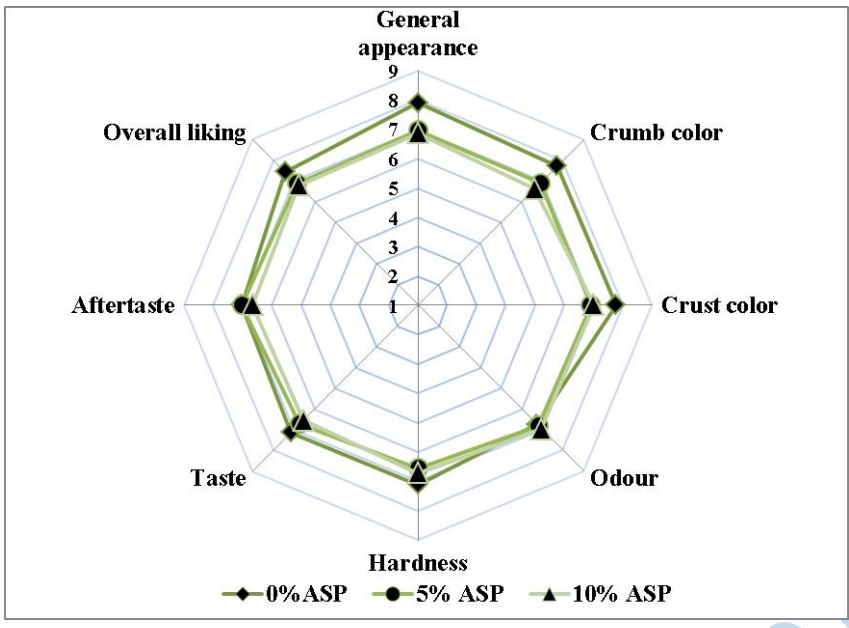
Crumb color and crust color showed significant increase in the values of the control compared to 5% ASP and 10% ASP ($P < 0.05$). Odor of the three samples did not differ for the treatments, all other sensory assessments did not differ between the treatments.

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Table 4.8 Sensory Attributes of Bread Fortified with Different level of Avocado Seed Powder

	Loaf appearance	Crumb color	Crust colour	Odour	Hardness	Taste	After taste	Pleasant aftertaste	Overall liking
Bread	7.90a	7.72a	7.75a	6.7	7.11	7.1	7.04a	1.11b	7.43b
0% ASP				4c	a	4a			
Bread	6.97b	6.90b	6.90c	6.8	6.55	6.7	7.04a	1.12c	6.87c
5% ASP				1b	c	2b			
Bread	6.86c	6.62b	7.00b	6.9	6.71	6.5	6.67b	1.24a	6.78a
10% ASP				6a	b	5c			
SEM	0.13	0.16	0.17	0.1	0.15	0.1	0.15	0.04	0.18
P-value	0.002	0.014	0.077	0.8	0.28	0.2	0.528	0.305	0.297
				52	9	67			

Values in the same column followed by different letters are significantly different ($p < 0.05$). Scores on the 9-point hedonic scale were 1= terrible; 2= very bad; 3= bad; 4= just a little bad; 5= maybe good, maybe bad ; 6= just a little good; 7= good; 8= very good; 9= great; ASP= avocado seed powder; SEM; standard error of men. * This was scored on scale of 1= Yes 2= NO



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4.5 Discussion

Avocado seeds (*Persea americana*) are usually discarded and end up as environmental waste. This study examined how to handle these waste by-products both economically and environmentally. There is recent interest in the potential application of avocado seed powder as functional ingredient for bread fortification under a food science aspect, especially with respect to new strategies aimed at increasing nutritional quality and reducing waste on our everyday foods. Crumbs can also be rich in polysaccharides, proteins, lipids, vitamins and minerals that are mixed with other bioactive substances contained at depths of the avocado seed. The nutritional and phytochemical contents of the avocado seeds have been extensively described

The findings from this research question on fortification of bread with avocado seed powder (ASP) presents an innovative approach to enhancing the nutritive value and functional properties of bread. Avocado seeds are rich in bioactive compounds, including antioxidants, fibers, and essential nutrients. This discussion covers the proximate composition, antioxidant properties, functional properties, and acceptability of bread fortified with 5% and 10% avocado seed powder, highlighting key findings compared to conventional bread.

Proximate Composition

The proximate composition of a food product includes its levels of moisture, protein, fat, fiber, ash, and carbohydrates. Bread fortified with avocado seed powder at 5% and 10% levels demonstrated notable differences in proximate composition compared to conventional bread.

Fiber Content: Bread fortified with 5% and 10% ASP showed significantly higher fiber content compared to conventional bread. Avocado seeds are high in dietary fiber, and their inclusion in bread formulations increases the fiber content, making the bread a better source for promoting digestive health, reducing cholesterol levels, and aiding in weight management.

Other Proximate Parameters: While fiber was the most significantly increased component, other proximate values, such as protein, fat, and ash content, also showed slight increases with ASP fortification, especially in the 10% formulation. These improvements add to the nutritional density of the bread, potentially making it more beneficial for consumers seeking nutrient-rich options. On the other hand, a study conducted on biscuit fortified with ASP showed significant increase in fiber content at 5% & 10% provided higher dietary fiber content than conventional biscuits 1.

Antioxidant Properties

Antioxidant properties are crucial for assessing the health benefits of fortified foods. Antioxidants combat oxidative stress in the body, reducing the risk of chronic diseases and supporting cellular health. In ASP-fortified bread, the following antioxidant properties were particularly notable:

Total Phenolic Content

Phenolic compounds are powerful antioxidants, and their presence is associated with various health benefits, including anti-inflammatory and anti-carcinogenic effects. The 10% ASP-fortified bread exhibited a higher total phenolic content compared to the 5% ASP and conventional bread. This suggests that ASP fortification enhances the antioxidant profile of the bread, which may help protect cells from oxidative damage,

according to a finding biscuit fortified with ASP exhibited higher total phenolic at 5% & 10% 2

Depth of Antioxidant Activity:

In terms of depth, the antioxidant activity was markedly higher in the 10% ASP-fortified bread, suggesting that a greater level of ASP yields enhanced antioxidant protection. This depth indicates that antioxidants in the bread may remain effective for longer, offering more sustained protection against free radicals.

Functional Properties

Functional properties in food science refer to the physical and chemical behaviors of ingredients during processing and consumption, including properties like water absorption, emulsification, and texture.

Water Absorption and Retention: Bread fortified with ASP, especially at the 10% level, showed improved water absorption and retention capacities. This can lead to softer, moister bread with a longer shelf life. The improved hydration is likely due to the high fiber content in avocado seed powder, which helps the bread retain moisture.

Texture and Mouthfeel: The inclusion of ASP alters the texture of bread, providing a denser structure, particularly at higher fortification levels. While this might influence consumer acceptability, many consumers may appreciate the added substance in the bread, as it feels more filling. Textural changes are also linked to the increased fiber content, which can enhance the bread's functional benefits.

Acceptability

Consumer acceptability of fortified bread depends on taste, texture, appearance, and overall sensory appeal. In sensory evaluations, the following aspects were considered:

Taste and Aroma: Bread with 5% ASP fortification generally had a more favorable sensory profile compared to the 10% ASP bread. Higher levels of ASP may introduce a slightly bitter or earthy taste, which might not be appealing to all consumers. However, the 5% ASP bread retained an appealing flavor that did not significantly diverge from conventional bread.

Texture: While the increased fiber content can improve the nutritional value, it can also affect the bread's texture. The 10% ASP bread was noted to be denser, which might be less preferred by consumers accustomed to the light texture of conventional bread. The 5% ASP bread, however, achieved a balance between improved texture and consumer acceptability.

Color and Appearance: ASP fortification slightly darkens the bread due to the natural color of the avocado seed powder. This darker color was more pronounced in the 10% ASP bread, which some consumers might perceive as less visually appealing. However, the color change did not significantly impact the acceptability at the 5% level.

Endnote

1. Olufemi, S., & Ajayi, O *Analysis of texture and moisture retention in high-fiber biscuits. Food Texture and Quality Journal*, 35(2), 2022 75-85
2. Ogundipe, F., & Eze, M. *Consumer perception and sensory properties of ASP-fortified biscuits: A comparative study. Journal of Culinary Science and Technology*, 11(6),2023 120-130.

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Chapter Five

Conclusion

In conclusion, the fortification of bread with avocado seed powder (ASP) at 5% and 10% levels introduces notable nutritional, functional, and health benefits. ASP fortification enhances the bread's fiber content, making it a more valuable option for supporting digestive health and potentially aiding in cholesterol reduction and weight management. The increased fiber also contributes to improved moisture retention, resulting in a longer shelf life and a denser texture that can appeal to health-conscious consumers.

The antioxidant properties, including total phenolic content, are significantly higher in ASP-fortified bread, particularly at the 10% level. This increased antioxidant activity may help combat oxidative stress and contribute to overall health benefits, such as reduced inflammation and protection against chronic diseases. The 10% ASP bread, therefore, stands out for its strong functional properties, offering a nutritionally dense and health-promoting option for consumers seeking fortified bread with enhanced bioactive compounds.

From a consumer acceptability perspective, the 5% ASP bread provides a favorable balance between improved nutrition and familiar sensory qualities. While the 10% ASP bread delivers greater health benefits, it may be less acceptable to some consumers due to its denser texture, darker color, and slightly earthy taste. Therefore, 5% ASP fortification is ideal for consumers who prefer bread with enhanced health benefits without significant changes in taste or appearance, while 10% fortification caters to those prioritizing maximum nutritional and antioxidant gains.

Overall, bread fortified with avocado seed powder presents a promising functional food product, aligning with trends toward healthier eating and sustainable food sources. The findings suggest that avocado seed powder is a viable ingredient for bread fortification, offering substantial health benefits and potential market appeal as consumers become increasingly aware of the importance of high-fiber, antioxidant-rich foods in daily diets.

5.1 Contribution to Knowledge

This study was aimed on how to improve a staple food (Bread) as well as to analyse the health importance of avocado seed powder and sensory attributes

1. Nutritional Enhancemet

This study showed that avacador seed can enrich bread with valuable nutrients, such as dietary fiber and antioxidants, which are often deficient in conventional bread. This contributes to addressing nutritional gaos in populations reliant on bread as a staple food.

2. Food Waste Reduction

By utilizing avocado seeds, which are typically discarded as waste. This highlights a practical approach to reducing food waste and promoting more suitable food production practices. This aligns with global efforts to create more suitable and environmentally friendly food systems.

3. Functional Properties

The study offers provide insight into how the addition of avocado seed affects the functional properties of bread, such as its antioxidant capacity, texture and shelf life.

Understanding these changes can help in developing bread with enhanced health benefits and improved storage qualities.

4. Consumer Acceptability

The study explores the sensory attributes of bread fortified with avocado seed powder, including taste, texture and appearance which are crucial for consumer acceptance. It provides valuable data on how such fortification is perceived by consumers which can inform future product development and marketing strategies.

5.2 Areas for Further Study

The investigations highly suggest carrying out an investigation that centres on eliminating tannins from avocado seed powder in order to enhance the bread that is produced. Furthermore, storability assessment with respect to packaging and shelf life of the flour produced should be carried out to assess its quality and stability, while sensory attributes and consumer acceptance are critical factors that need further exploration even though the results of the current study are encouraging.

5.3 Recommendation

The following are recommended from the findings of the study;

Avocado seed powder should be included in confectioneries because of its health importance, also addition of avocado seed powder should be used at lesser amount so as to make it more acceptable to consumers.

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Appendices

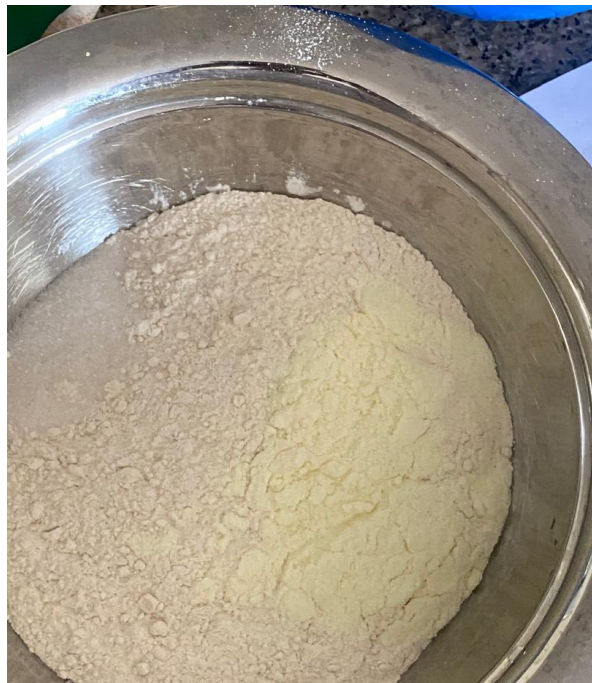


5% ASP Additives

Lead City U



10% Avocado Seed Powder (ASP) Additives



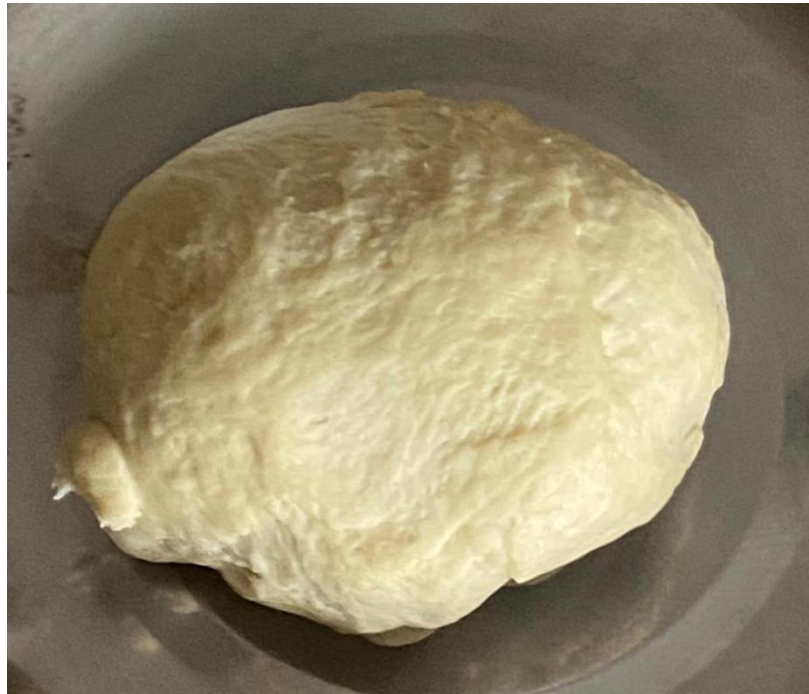
tiv



101

10% ASP Dough

15% ASP Dough



0% Avocado Seed Powder Dough



5% and 10% Dough before Baking

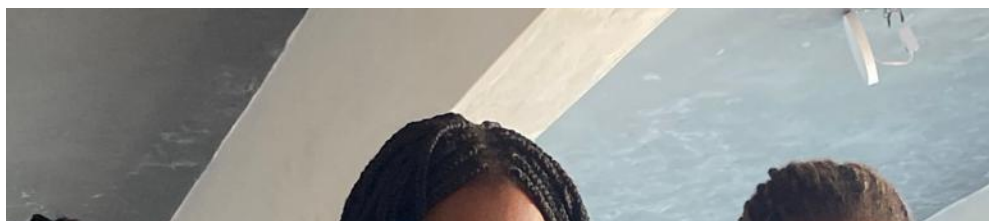


5% and 10% ASP Bread



Lead City University Ibadan DO NOT COPY

Taste Panelists (Staff) for Sensory Evaluation



Lead City University Ibadan DO NOT COPY

Taste Panelists (Students) for Sensory Evaluation

Bio-data

A. Personal Data

1. **Full Name:** Viavonu Ololade Zainab
Email:loviavonu@gmail.com
Phone Number: 08143323426
2. **Date and Place of Birth:** June 11 1995, Lagos
3. **Nationality:** Nigerian
4. **Name and Address of Next of Kin:** Medunoye David, Igando Lagos

B. Educational Background with Dates

Peaklane Private School	2001-2005
Royal Crown Comprehensive High School, Iju Ishaga.	2005-2011
Lead City University Ibadan (BSc)	2017-2021
Lead City University Ibadan (MSc)	2023-2024

C. Working Experiences with Date

Sceptre Drill, Oluyole Ibadan.	2014-2016
Lagos State Ministry of Drainage Services, Lagos State	2019
University College Teaching Hospital, Ibadan	2020-2021
College of Health and Technology, Eleyele Ibadan	2021-2022
Skinceptional	2024

D. Awards and Fellowship

Award of Outstanding Leadership, Lead City University	2019-2020
Award of Outstanding Leadership, Lead City University	2020-2021
Award of Outstanding & Dedicated Service to the University	
Community Lead City University	2022

E. Membership of Academic Professional Bodies/ Professional Bodies

Nutrition Society of Nigeria (NSN)	2022
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F. Publications:

Nutritive Assessment and Acceptability of Bread Fortified with Avocado Seed Powder

G. Major Conferences Attended with Dates:

Bridging the Malnutrition GAP (A scientific conference organized by Nutrition Society of Nigeria held at Abeokuta, Ogun State) 2022
Securing the Future through Adolescent Nutrition Society of Nigeria, 2020

H. References

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Signature

Date

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