UNIVERSITY OF CAPE COAST

DEVELOPMENT OF A FUNCTIONAL FOOD ADDITIVE FROM UNDERUTILIZED CROPS; TURKEY BERRY AND AIDAN FRUIT

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2025

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DEVELOPMENT OF A FUNCTIONAL FOOD ADDITIVE FROM UNDERUTILIZED CROPS; TURKEY BERRY AND AIDAN FRUIT

BY

EUNICE DAVIS

Thesis submitted to the Department of Agricultural Engineering of the College of Agriculture and Natural Science, University of Cape Coast, in partial fulfilment of the requirements for the award of Master of Philosophy degree in Food and Post – Harvest Technology

2025

DECLARATION

Candidate's Declaration

I hereby declare that this thesis is the result of my own original research and that no part of it has been presented for another degree in this university or elsewhere.

Candidate's Signature: .... Date: ....

Name: Eunice Davis

Supervisors' Declaration

I hereby declare that the preparation and presentation of the thesis was supervised in accordance with the guidelines on supervision of thesis laid down by the University Of Cape Coast.

Principal Supervisor's Signature:………………… Date: ....

Name: Professor Ernest Teye

ABSTRACT

The demand for natural food additives is rising as consumers increasingly seek healthier, safer alternatives to synthetic compounds. Natural additives play a vital role in enhancing food quality, extending shelf life, and contributing to dietary diversity, aligning with efforts to address global food challenges. Aidan and turkey berries remain underutilized fruits, with excellent macro and micronutrients, as well as phytochemical and antimicrobial properties. However, little research focuses on the potential of formulating a functional product as well as the proximate, physicochemical, and phytochemical properties of the crops. Hence, the present study was designed to develop a functional food additive from Aidan fruit and turkey berry. Eight samples including single (Aidan and turkey berry) as well as composite blends of these fruits were formulated and assessed for physicochemical, phytochemical, and sensory properties using a completely randomized design. Results revealed significant variations in proximate and phytochemical properties of Aidan fruit and turkey berry. Typically, turkey berries had 6.10%, 3.18%, and 7.37% increase in moisture, ash, and protein relative to Aidan fruit (4.49%, 2.09% and 6.57%) respectively. Similarly, 36.9%, 159.1%, and 142.6% increases in flavonoid, phenol, and carotenoid were recorded in aidan fruit compared to turkey berry (22.54%, 97.7% and 133.6%) respectively. Furthermore, the results indicated that a composite of turkey berry and aidan fruit tends to improve the phytochemical, proximate, and sensory attributes of formulated functional products. It was clear that, the proximate, phytochemical, and mineral composition of functional product showed a direct association with

increasing turkey berry proportion within the composition. Thus, properties such as ash, fiber and moisture content, increased with increasing turkey berry in the composition. Similarly, carotenoids, flavonoid and phenolic properties were higher with samples of higher proportion of aidan fruit compared to turkey berry. Regarding sensory attributes, taste, texture, appearance, aroma and overall acceptability, they were significantly higher for samples T(90):A(10) and T(82.5):A(17.5), compared to samples T(0):A(100) and T(100):A(0). Additionally, functional products formulated from composition recorded higher overall acceptability compared to single products. These findings emphasize the promising role of Aidan and turkey berry as sustainable, nutrient-rich natural additives, offering a pathway to improve food quality and health outcomes. Also, it was clear that a blending of aidan fruit and turkey berry significantly improves nutritional quality but this is contingent of proportion in the blend. Despite the aforementioned, further studies could explore how various processing techniques and storage conditions could influence quality parameters of the functional product.

ACKNOWLEDGEMENT

Firstly, I express my deepest gratitude to the Almighty God for preserving my well-being and guiding me through this academic journey. I extend my heartfelt appreciation to my supervisor, Professor Ernest Teye, and senior colleague Vincent Agyemang Opoku, for their exceptional mentorship, unwavering patience, insightful critiques, and valuable recommendations throughout my research endeavor. Your contributions are immensely appreciated. I am also deeply grateful to my family, especially my grandparents, for their unwavering support and encouragement throughout my academic pursuits. Their sacrifices and belief in my abilities have been a constant source of motivation. I would like to acknowledge my fellow researchers and lab mates for creating a collaborative and stimulating environment that fostered intellectual growth and camaraderie.

DEDICATION

I dedicate this work to my lovely grandparents, Mr. Edwin Francis Kojo Mbeah and Mrs. Beatrice Efua Mbeah.

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CHAPTER ONE

INTRODUCTION

Background to the Study

Increasing global population growth has led to increased food demand, creating a significant challenge for agriculture to meet nutritional requirements. Despite increased food production to meet the demand of the ever-increasing human population, food spoilage and inadequate nutritional quality impede efforts to enhance food production, particularly in Sub-Saharan Africa (SSA) (Vos & Bellù, 2019). Agricultural losses due to food spoilage exacerbate food insecurity, while poor nutrition results in "hidden hunger," where individuals consume sufficient calories but lack essential micronutrients (De Corato, 2020).This deficiency causes health problems and impedes development, especially among vulnerable populations. Numerous techniques have been used to improve nutrition and food quality as well as shelf-life in the food industry (De Corato, 2020). In this context, food additives play a crucial role in enhancing the appearance, nutritional quality, shelf life and acceptability of various foods (Sulieman et al., 2023).

Despite the aforementioned relevance of food additives, the food industry utilizes synthetic additives to enhance food quality and longevity, raising concerns about long-term health effects (Warner, 2024). Numerous publications indicate that synthetic and artificial additives, such as artificial colorants, benzoate preservatives, non-caloric sweeteners, emulsifiers, and their breakdown products, may have harmful effects. These include an increased risk of mental health disorders, attention deficit hyperactivity disorder (ADHD), cardiovascular disease, metabolic syndrome, and potential carcinogenic effects (Kraemer et al., 2022).

Natural additives and extracts are becoming increasingly popular as consumer habits evolve. As health-conscious consumers seek safer options, there is a growing demand for natural, functional food additives that can enhance nutritional value and extend shelf life (Carocho et al., 2015). Functional foods, which provide health advantages beyond essential nutrition, have garnered attention. These foods are often enriched with bioactive compounds that promote well-being and reduce disease risk. Developing functional food additives from natural sources, such as indigenous fruits, presents a promising solution to challenges related to food quality, nutrition, and safety (Ayala-Zavala et al., 2011).

Aidan fruit (*Tetrapleura tetraptera*) and Turkey berry (*Solanum torvum*) are underutilized fruits with potential as functional food additives that enhance nutritional value, sensory characteristics, and specific health benefits (Donno et al., 2018).These natural additives have traditional medicinal uses in Africa and Asia. Aidan, locally termed as “Prekese”, is rich in phytochemicals with antioxidant, anti-inflammatory, and antimicrobial properties. Aidan fruit, used in traditional medicine and as a spice in West Africa (Korang et al., 2023; Ojewole & Adewunmi, 2004), contains 16 bioactive compounds, with 2-thiopheneethanol being the most abundant (58.77%) (Nsofor et al., 2023). Other significant compounds include curcumin and N-benzyl stearamide, fatty acid amide hydrolase inhibitors (Nsofor et al., 2023). It also contains 18 amino acids, with leucine, phenylalanine, and valine being the most prevalent (Nsofor et al., 2023), which enhances its value as a protein source. Aidan fruit components exhibit varying antimicrobial activities (Okechukwu et al., 2022). Essential oil and oleoresin extracts from aidan inhibit *Escherichia coli* and *Staphylococcus aureus*, with effectiveness increasing with concentration. The fruit's active compounds help reduce oxidative stress-related diseases and suppress microbial infections. Thus, Aidan fruit shows potential in food preservation, pharmaceuticals, and functional foods with health benefits (Mensah et al., 2024). Turkey berries are nutritious with antidiabetic and antihypertensive benefits. It is recognized for its rich nutritional content as well as its strong antioxidant and antimicrobial properties. It contains steroids, saponins, flavonoids, alkaloids, and vitamins that contribute to its antioxidant, cardiovascular, and immunomodulatory effects (Berry ,C .2021). The antioxidant properties of turkey berries are characterized by their high total phenolic content and strong antioxidant activity. Research on functional beverages made with turkey berries has demonstrated notable impacts on phytochemical compositions (Anggriani et al., 2023). These results suggest the possibility of turkey berries in the development of natural antimicrobial agents. This study explored the development of a functional food additive from these fruits to promote local plant resource utilization (Ogwu & Osawaru, 2022).

The growing demand for natural functional food additives is driven by health-conscious consumers and potential benefits of bioactive compounds (Deshmukh & Gutte, 2024).This trend could address food security, improve nutrition, and create economic opportunities in the cultivation regions. Functional additives from Aidan and Turkey berries align with the global shift towards natural ingredients. Research on a Turkey berry spice mixture containing ginger and anchovy powder showed promising antioxidant properties and sensory appeal, suggesting commercial potential (Golly et al., 2018). Aidan fruit shows promise as a functional food product or nutraceutical, warranting further research on its health benefits and food industry applications. Its versatility extends to food preservation and natural cosmetics, with studies exploring its use as a natural preservative and anti-aging formulation owing to its antimicrobial and antioxidant properties (Johnson et al., 2024; Lee & Kim, 2025).

Although promising, further research is needed on nutritional profiles, combinations with other ingredients, and compound stability during processing and storage. The development of functional food additives from Aidan and Turkey berry fruits offers opportunities for innovation in the food industry, providing nutritional benefits and unique flavors. Comprehensive studies of their interactions with other food components and their stability during processing and storage are essential. This study aimed to develop a novel food additive that enhance nutritional value and health benefits without the risks of artificial additives. Developing a functional food additive from the Aidan and Turkey berries addresses food security, nutrition, and safety concerns, creating sustainable, health-promoting food solutions that benefit consumers and local economies. These findings could significantly impact the food industry by transforming the food preservation and fortification methods. Utilizing natural compounds from Aidan and Turkey berry fruits, manufacturers may produce healthier products with clean labels, appealing to health-conscious consumers. Additionally, this research could promote the cultivation and commercialization of these fruits, creating economic opportunities for farmers in their native regions.

Problem statement

The increasing global population poses a significant threat to food security, as food production may struggle to meet the growing demand (McDonald, 2010). Additionally, post-harvest food spoilage further reduces food quality and availability, exacerbating the challenge of ensuring an adequate food supply (Kiaya, 2014).While the food industry relies on additives to address these issues, the majority of these additives are synthetic and may pose significant health risks to consumers (Carocho et al., 2014).

The food industry's reliance on synthetic additives has raised concerns due to potential health risks (Sultana et al., 2023).For instance, artificial food colorings like Red 40 and Yellow 5 have been linked to hyperactivity and attention problems in children, while sodium nitrite in processed meats may form carcinogenic nitrosamines. Preservatives such as butylated hydroxyanisole (BHA) and butylated hydroxytoluene (BHT) have shown potential carcinogenic effects in animal studies. Additionally, artificial sweeteners like aspartame have been associated with headaches and potential neurological effects, and monosodium glutamate (MSG) may cause adverse reactions in sensitive individuals.

In response to these concerns, there has been a paradigm shift towards natural and functional food additives (Carocho et al., 2015). This shift is particularly vital in the context of developing countries, where micronutrient deficiencies remain a pervasive health concern, with Ghana serving as a prominent example (Tandoh & Asamoah, 2022). In this context, two seasonal fruits, turkey berry, and Aidan fruit, hold exceptional promise as natural sources of nutrition and medicinal properties. However, a considerable challenge persists in their utilization due to the high perishability of turkey berries and the dearth of comprehensive research and processing initiatives aimed at optimizing their nutritional and medicinal potential for application as food additives (Adu et al., 2018). Aidan (*Tetra pleura tetraptera*) and turkey berry (*Solanum torvum*) fruits have emerged as promising candidates for developing such additives (Akin-Idowu et al., 2011; Anggriani et al., 2023). These fruits are rich sources of antioxidants, antimicrobial compounds, phytochemicals, and nutritional elements, making them potential alternatives to synthetic additives (Mensah et al., 2024; Nadeeshani et al., 2021).These underutilised crops offer numerous benefits, including antioxidants that help prevent oxidative stress and reduce chronic disease risk, antimicrobial compounds that can extend food shelf life naturally, and phytochemicals that enhance nutritional value. Natural pigments from these fruits could serve as safer alternatives to artificial food colourings, while fibre-rich extracts may improve gut health and digestion. Furthermore, bioactive compounds from Aidan and turkey berry could potentially enhance the immune-boosting properties of fortified foods, and their natural flavour compounds may provide healthier flavouring options (Martina et al., 2021; Mensah et al., 2024).

However, despite their potential, the development of functional food additives from Aidan and turkey berry fruits remains largely unexplored. There is a lack of comprehensive research on the extraction, characterization, and application of bioactive compounds from these fruits in food systems. Thus, the problem lies in the limited scientific understanding of how to effectively harness the beneficial properties of Aidan and turkey berry fruits to create safe, efficient, and consumer-acceptable functional food additives. This gap in knowledge hinders the food industry's ability to leverage these natural resources as alternatives to synthetic additives, potentially missing an opportunity to address food security concerns while meeting the growing consumer demand for healthier, more natural food products. Hence, the present research aims to explore the potential of Aidan fruit and turkey berry as sources of natural and functional additives in food products, addressing the need for safer alternatives to synthetic additives while potentially improving the nutritional profile and health benefits of processed foods.

General objective

This research aims to develop a functional food additive from underutilized crops turkey berry and Aidan fruit.

Specific objectives

Specifically, the present study aimed to;

1. Evaluate the physicochemical and phytochemical properties of raw turkey berry and aidan fruit.

2. Determine the physicochemical and phytochemical properties of formulated single and composite aidan and turkey berry food additive.
3. Evaluate the sensory and overall consumer acceptability of formulated food additive.

Research hypothesis

The research hypothesis to be tested in the present study includes;

1. Functional food additives could be developed from single and composite aidan and turkey berry fruit.
2. Additive formulated from single and composite aidan and turkey berry would differ in their physicochemical properties.
3. Phytochemical properties would differ among additives formulated from single and composite aidan and turkey berry powder.
4. Formulated functional additives would vary in their sensory and overall consumer acceptability.

Significance of the study

By investigating Aidan fruit and turkey berry as potential natural additives, this research contributes to the growing demand for clean label products and addresses consumer concerns about synthetic additives in processed foods. The study explores the possibility of enhancing the nutritional profile of food products through the incorporation of these natural additives, potentially leading to the development of functional foods with added value for consumers. Aidan fruit and turkey berry are relatively underexplored in food applications. This research could lead to increased utilization of these plants, potentially benefiting local economies and promoting biodiversity conservation. Natural additives may offer safer alternatives to synthetic ones, potentially reducing the risk of adverse health effects associated with certain artificial additives while maintaining or improving food quality and shelf life. Utilizing plant-based additives aligns with sustainability goals in the food industry, potentially reducing reliance on synthetic chemicals and promoting the use of renewable resources.

This study will contribute to the scientific understanding of the properties, applications, and potential benefits of Aidan fruit and turkey berry in food systems, expanding the current body of knowledge in food science and technology. If these natural additives prove to have significant nutritional or bioactive properties, their incorporation into food products could contribute to improved public health outcomes through enhanced nutrient intake or specific health-promoting effects. The findings of this study could inspire new product formulations and innovations in the food industry, leading to a wider range of healthier and more natural food options for consumers. Successful application of these natural additives could create new market opportunities for both the food industry and producers of Aidan fruit and turkey berry, potentially stimulating economic growth in related sectors. This research may provide valuable data to inform food safety regulations and labeling requirements for natural additives, contributing to the development of appropriate guidelines for their use in food products.

CHAPTER TWO

LITERATURE REVIEW

Overview of functional food additives

Substances intentionally incorporated into foods for specific technological or health-enhancing purposes are known as functional food additives. These additives are essential for enhancing food quality, boosting nutritional content, and prolonging shelf life (Abedi-Firoozjah & Tavassoli, 2024). The food industry has seen a surge of interest in developing functional food additives using natural components, driven by growing consumer demand for healthier and more natural food choices. This shift is motivated by worries about artificial additives and an increased focus on health and well-being (Pin & Daniel, 2023). Bioactive compounds, which can be extracted and used as functional food additives, are plentiful in natural sources such as fruits, vegetables, plants, herbs, spices, and food industry byproducts. These natural additives offer various health advantages and can replace synthetic compounds, which are becoming less popular among consumers (Vilas-Boas et al., 2021).

Natural antioxidants derived from fruits, vegetables, herbs, and spices have gained significant attention as functional food additives due to their numerous beneficial properties (Gutiérrez-del-Río et al., 2021; Yanishlieva & Marinova, 2001). These plant-based sources are rich in phenolic compounds, carotenoids, vitamins, and microelements. As consumers become more informed, the food industry is investigating natural alternatives that maintain food quality while offering potential health advantages (Tachie et al., 2023; Taouzinet et al., 2023).This trend is driven by heightened consumer awareness, growing demand for clean label products, and efforts to promote sustainable practices.

Turkey berry and its potential as a functional food ingredient

Turkey berry (*Solanum torvum*) is a wild plant with potential as a functional food ingredient owing to its high antioxidant and bioactive compounds. This member of the Solanaceae family is found in Africa, Asia, and South America and is used in various cultural culinary and medicinal practices (Anggriani et al., 2023). It is a native/indigenous fruit vegetable with notable nutritional and medicinal benefits, this makes it a valuable resource to address malnutrition and food insecurity in the country and is recognized by several local names, it is commonly referred to as "kwahu nsusua" in Ghana. It is rich in vitamins, minerals, and antioxidants, is used to treat health issues, and is an essential part of traditional cuisine. The plant has cultural significance, offers economic opportunities for small-scale farmers, and is sustainable because of its ease of growth. Their widespread availability ensures accessibility (Nyadanu & Lowor, 2015).

Turkey berry exhibits a favorable nutritional profile, characterized by high concentrations of protein, carbohydrates, and minerals (Nadeeshani et al., 2021). The fruits of the crop is an excellent source of essential vitamins including C, D, and E in comparison to other Solanum species (Nadeeshani et al., 2021).The plant is replete with bioactive compounds, contributing to its potential health benefits. The nutritional composition of turkey berry encompasses phenolic compounds renowned for their antioxidant properties. Furthermore, it contains flavonoids, including anthocyanin and flavanols, which enhance its antioxidant capacity. Additionally, alkaloids, which exert various physiological effects, are present (Martina et al., 2021). The berry comprises steroids, carotenoids, saponins, and an array of antioxidant vitamins. Turkey berry, although less extensively researched than other berries, shares numerous bioactive compounds with more widely studied varieties such as blackberries, blueberries, and strawberries (Golovinskaia & Wang, 2021).

Turkey berry *(Solanum torvum)* offers extensive health benefits due to its rich phytochemical content, including flavonoids (quercetin, kaempferol, rutin), phenolic acids (chlorogenic acid, caffeic acid), saponins (solanine, solasodine), and carotenoids (lutein, zeaxanthin). These bioactive compounds contribute to its antioxidant, cardiovascular-protective, and immunomodulatory effects, making it a valuable functional food. Its bioactive compounds may potentially contribute to the prevention of inflammatory disorders, cardiovascular diseases, and various forms of cancer (Martina et al., 2021). Turkey berry, is a nutritious fruit with various health benefits and is utilized in diverse culinary traditions and traditional medicine. It is consumed both raw and cooked, frequently incorporated into stews and curries for flavor enhancement. Traditionally, it has been employed to address digestive, respiratory, and dermatological conditions (Ramamurthy et al., 2016).

The consumption of turkey berry is associated with antioxidant effects, cardiovascular benefits, and immunomodulatory properties, suggesting its potential in the prevention of inflammatory disorders, cardiovascular diseases, and certain malignancies (Ningsih et al., 2021; Jimenez-Garcia et al., 2018).

Although the phytochemical, nutritional, and functional properties of turkey berry (*Solanum torvum*) are well-documented, there is limited research on its development and application as a standardized functional food ingredient. This research is therefore justified to bridge the gap between traditional knowledge and scientific innovation by investigating how turkey berry can be harnessed as a culturally relevant, sustainable, and health-promoting functional food ingredient. Future research should aim to validate traditional uses and explore potential therapeutic applications, underscoring the necessity for further scientific investigation into its nutritional and phytochemical properties and health benefits.

Aidan fruit and its potential as a functional food additive

Aidan fruit (*Tetrapleura tetraptera*) shows promise as a functional food ingredient due to its unique properties and health benefits. The dried pods contain bioactive compounds contributing to its medicinal properties and distinct flavor (Akin-Idowu et al., 2011). It is widely used in West African cuisine to address health concerns (Ojewole & Adewunmi, 2004). Studies highlight its antioxidant, anti-inflammatory, and antimicrobial effects, especially in postpartum care .The fruit's ability to enhance flavor and provide health benefits makes it suitable for functional food applications. However, further research is needed to fully understand its bioactive compounds, mechanisms of action, safety profile, and optimal processing methods. Sustainable sourcing and cultivation should also be considered as interest grows.(Korang et al., 2023). Aidan fruit bridges traditional knowledge with modern food science, showing potential in developing functional foods.

The fruit's potent, aromatic scent, attributed to crude lipids, enhances its application as a flavoring agent and insect repellent (Essien et al., 1994).These distinctive botanical characteristics contribute to its significance in culinary, medicinal, preservative applications and highlight its importance in both traditional practices and modern scientific investigations, underscoring the need to conserve this essential species for upcoming generations. *Tetrapleura tetraptera*, commonly referred to as the Aidan fruit or Prekese in Ghana, is a plant indigenous to West Africa that offers substantial nutritional and medicinal benefits. Its composition comprises a significant proportion of carbohydrates (58.48%-63.86%), along with proteins, lipids, and dietary fiber, which support digestive health and facilitate weight management. The fruit is rich in potassium (251.22-288.62 mg/g), an essential element for cardiac function, blood pressure regulation, and neural and muscular operations. It also contains considerable quantities of calcium (182.11-200.02 mg/g), which is vital for skeletal health and cellular activities, as well as manganese (322.00-342.00 mg/g), crucial for osteogenesis, wound healing, and metabolic processes.(Mensah et al., 2024).

Furthermore, the Aidan fruit possesses a diverse array of phytochemicals, including phenols, flavonoids, saponins, tannins, and alkaloids. These phytochemicals, contributes to its medicinal properties. Phenols and flavonoids are antioxidants with potential anti-inflammatory effects, whereas saponins may reduce cholesterol levels and exhibit anti-carcinogenic properties. Tannins are astringent compounds with antimicrobial effects, whereas alkaloids have various physiological effects. Aidan fruit extracts exhibit antioxidant, anti-inflammatory, and antimicrobial activities, rendering them relevant for traditional and modern medicine. The nutritional profile and bioactive compounds of the fruit make it a focal point for health-promoting research. The pulp is utilized as a spice and for medicinal purposes, whereas the seed, which is often discarded, also contains valuable metabolites and antimicrobial properties (Korang et al., 2023).

Aidan fruit can substitute vanilla powder in foods, such as cookies, enhancing nutritional and sensory qualities (Olatoye et al., 2020). Its phytochemical composition provides antioxidant, antimicrobial, anti-inflammatory, antidiabetic, antiparasitic, and antiproliferative effects. These properties help reduce blood pressure, enhance immune function, treat malaria, manage diabetes and hypertension, and potentially prevent cancer. The nutritional and medicinal attributes of the fruit are valuable for food processing, pharmaceuticals, and functional foods (Essien et al., 1994; Mensah et al., 2024).

Physicochemical properties of Aidan fruit

Aidan fruit/Prekese, is a West African plant valued as a spice and medicinal ingredient due to its abundance of secondary metabolites, including alkaloids, flavonoids, tannins, saponins, and glycosides. These compounds give it a fragrant and pungent aroma similar to that of vanilla (Olatoye et al., 2020)Processing techniques can alter the physicochemical properties of Aidan fruit. Roasting at 140°C for 10 min reduces fat and sugar content while increasing raw fiber (Eyenga et al., 2020).This treatment also increased the phenolic content and antioxidant capacity of fruit extracts Gamma irradiation of up to 10kGy affects carbohydrate, protein, and trace element levels without compromising safety (Darfour et al., 2014).The versatile properties of *T. tetraptera* make it valuable in traditional medicine and culinary applications. Its unique flavor and aroma enhance various dishes and herbal preparations in West Africa.

Additionally, its bioactive compounds offer potential health benefits, making it an attractive functional food ingredient and a natural preservative in the food industry.Aidan fruit exhibits a diverse array of physicochemical properties that contribute to its nutritional and therapeutic value. The fruit contains various bioactive components, including phenols, flavonoids, and amino acids (Nsofor et al., 2023),Its antioxidant properties are particularly noteworthy, as demonstrated by its ability to neutralize free radicals and inhibit lipid peroxidation. These characteristics render Aidan fruit a significant component in traditional remedies and culinary applications, with potential utilization in food preservation and pharmaceutical industries (Okechukwu et al., 2022).Further research is necessary to elucidate the mechanisms through which Aidan fruit confers its health benefits. Clinical studies could provide valuable insights into the efficacy of Aidan fruit extracts in the prevention or treatment of various disorders. Furthermore, investigating sustainable cultivation and processing techniques for the Aidan fruit could enhance its accessibility and economic viability in both domestic and international markets.

Physicochemical properties of turkey berry

Solanum torvum, or turkey berry, has significant physicochemical properties making it suitable for functional food and medicinal uses. It is rich in bioactive substances like phenolic, flavonoids, and antioxidants (Anggriani et al., 2023; Teye et al., 2017),which contribute to its antioxidant capacity and health benefits. Environmental factors such as altitude, temperature, and pH affect turkey berry's physicochemical properties. These factors influence its physical appearance and chemical composition. Despite morphological differences, turkey berry remains genetically consistent across regions, not forming subspecies (Martina et al., 2021).

Turkey berry's physicochemical attributes include essential vitamins and minerals, making it a potential ingredient for functional foods and nutraceuticals. Its adaptability to various environments suggests it could be cultivated widely, supporting sustainable agriculture and food security. Turkey berry's physicochemical properties and phytochemical concentration make it suitable for functional foods and traditional medicine (Sharma et al., 2019). Its phytochemicals offer potential in food preservatives and pharmaceuticals, with future studies needed to understand their mechanisms and interactions in food and medicinal products.

Methods of processing and extracting functional foods

Blanching

Blanching, a crucial preprocessing method in agriculture, helps maintain quality and prolong shelf life by deactivating enzymes that cause unwanted changes in color, texture, and nutritional value. Recent innovations include superheated steam impingement blanching (SSIB), thermoultra sound blanching, combined radio frequency with hot water blanching, and infrared and steam blanching (ISB). These techniques offer advantages, such as enzyme deactivation, nutrient preservation, color retention, and texture conservation (Song et al., 2003). For example, SSIB is quick and effective without producing wastewater, whereas thermos-ultrasound blanching enhances the drying characteristics and decreases the energy consumption of sweet potatoes. Combining radio frequency with hot water blanching enhances color and texture preservation compared to using conventional hot water blanching alone (Xu et al., 2023).

Selecting the correct blanching technique is essential, as it affects the final produce quality. Hot water blanching effectively neutralizes enzymes, such as peroxidase and polyphenol oxidase, maintaining quality and extending shelf life (Chen et al., 2015). This method also enhances raw material quality and nutrient stability, and eliminates microorganisms (Wang et al., 2023). In the case of turkey berry (*Solanum torvum*), hot water blanching has been shown to reduce enzymatic browning and microbial load while preserving its bioactive compounds. Additionally, it helps lower antinutritional factors such as alkaloids and tannins, improving the fruit's overall nutritional quality and making it more suitable for processing into functional food ingredients (Baffour, 2022).Contemporary techniques, such as microwave, ohmic, and infrared blanching, provide benefits over traditional methods, potentially optimizing nutrient retention. The ideal blanching conditions vary based on the product and desired results (Salas-Tovar et al., 2018), requiring thorough evaluation and research to determine the most appropriate technique for each agricultural product to preserve its quality and nutritional content.

Drying

Preserving agricultural produce, extending its shelf life, and minimizing losses rely heavily on drying as a crucial postharvest technique. Solar kiln dryers have emerged as an economical and effective solution for drying timber and agricultural crops (Osae et al., 2020). These systems can maintain product quality without deterioration, while remaining financially viable. The agricultural drying process is highly energy-intensive due to significant variations in moisture content, the use of low drying temperatures, and the sensitivity of products to thermal and mechanical stress (Mellmann et al., 2019). Although conventional hot-air drying systems are commonly used, new technologies aim to achieve quicker moisture removal, enhance product quality, and reduce expenses (Das & Das, 2021).

Advanced methods include drying with inert solids, dielectric drying, fluidized bed drying, and hybrid approaches. As an alternative to traditional sun drying, solar drying technology enables the processing of fruits and vegetables under sanitary conditions, thereby meeting quality standards with minimal energy costs (Prasanna & Manjula, 2018). Heat-pump dryers, when combined with solar modes, can provide uninterrupted drying under various weather conditions. Non-thermal pretreatment methods, such as high-pressure, ultrasound, and pulsed electric field, can boost drying efficiency, shorten processing time, and preserve bioactive compounds (Osae et al., 2020). Integrating novel thermal techniques with hot-air drying has shown promise in decreasing the drying time and energy consumption and improving the overall efficiency of drying. (Onwude et al., 2016).

Milling

In food processing, milling plays a crucial role by breaking down larger food materials into smaller particles. This process is particularly important in cereal processing, where various mills, such as impact and roller mills, are used to grind seeds into flour (Choo, 2022). The application of milling extends to other products like nutmeg, wheat bran, ginger, and green tea powder (Sossa et al., 2021).Milling improves the physicochemical properties and functionality of food powders, enhancing their stability and versatility for different applications. The moisture level of food materials prior to grinding significantly affects the milling process and the resulting powder characteristics. Increased moisture can lead to greater cohesiveness and hinder powder flow, necessitating the optimization of moisture content (Jung et al., 2018). To produce high-quality, functional food powders, it is imperative to consider factors such as milling technique, moisture content, and material properties. Wet and dry milling are two key techniques in the food industry, each with distinct effects. Wet milling involves processing with excess water, while dry milling occurs without added moisture (Sayaslan et al., 2023).

Influence of processing methods on quality parameters of turkey berry and aidan fruit

Milling

Different milling methods affect the physical, chemical, and functional properties of milled products in various ways. Wet milling generally yields paste with reduced protein, ash, and lipid content but increased carbohydrate and amylose levels. This process also produces smaller granule sizes and enhances swelling power at elevated temperatures. Dry milling can disrupt crystalline structures, leading to reduced crystallinity and gelatinization enthalpy (Leewatchararongjaroen & Anuntagool, 2016). For example, in quinoa processing, wet milling yields fiber fractions of higher purity, while dry milling produces fiber with greater antioxidant activity (Ballester-Sánchez et al., 2020). Dry milling exhibits several advantages compared to wet milling, including water conservation and reduced environmental impact. Both wet and dry milling demonstrate efficacy in various applications. Wet milling is particularly effective in separating starch and other valuable components from cereal grains (Sayaslan et al., 2023) and can be beneficial in reducing mycotoxin contamination, such as deoxynivalenol (DON) in wheat.

Blanching

Blanching is a critical preprocessing technique for fruits and vegetables before further processing like freezing, canning, or drying. It involves brief heat exposure, typically using hot water or steam, to deactivate enzymes responsible for degradation (Halim et al., 2022). Research indicates that blanching significantly affects the drying process and quality preservation of turkey berry (Solanum torvum) fruits. Combining physical pretreatments, including blanching, enhances water diffusion during drying and maintains nutritional content (Barathiraja et al., 2022). Fruits subjected to abrasion and blanching demonstrated the shortest drying time, retaining 36% of their vitamin C content. This approach achieved the highest drying rate of 0.396 kg water/kgdb min−1, the maximum effective moisture diffusivity of 6.002 x 10^{-10} m^2/s, and a volumetric shrinkage ratio of 0.68 (Barathiraja et al., 2022). These findings suggest that combining blanching with other pretreatments significantly improves drying efficiency and quality retention of turkey berry fruits. Blanching, especially when combined with other physical treatments, optimizes the drying process and preserves essential nutrients in turkey berry, making it a valuable technique for food and pharmaceutical applications (Barathiraja et al., 2022).

Drying

The nutritional and functional characteristics of food products are greatly influenced by drying techniques. Different drying methods can affect the structure and functionality of major nutrients, such as proteins, starches, gums, and dietary fibers (Siddiqui et al., 2024).The temperature used in the drying process is a key factor for determining the quality of the end product. The quality and properties of Turkey berry (*Solanum torvum*) are substantially affected by the drying process. Researchers have explored various drying methods and pretreatments to enhance the drying procedure and to maintain the nutritional content of turkey berries. The dehydration behavior of turkey berries is largely determined by drying parameters such as inlet air velocity and temperature. Increased temperature and air velocity typically lead to faster drying rates and higher moisture diffusivities. For example, the highest moisture diffusion rate of 2.898 × 10−10 m^{-2} s^{-1} was observed at 70°C and 3.4 $m\text{-}^{2}$ s^{-1}.

The activation energy required for drying ranges from 36.82 to 45.63 kJ/mol under varying bed conditions (Rajendran et al., 2023).Notably, pretreatment methods can improve water diffusion during drying by eliminating the waxy layer on the peel. A combination of abrasion and blanching pretreatments resulted in the shortest drying time and preserved 36% of the vitamin C content. This indicates that suitable pretreatments can enhance the drying efficiency and nutrient retention. The quality, nutritional value, and physical properties of the turkey berries were significantly affected by the drying method. By optimizing the drying conditions and employing appropriate pretreatments, it is possible to preserve the beneficial properties of turkey berries, while ensuring efficient drying. (Barathiraja et al., 2022).

Effect of processing methods on physicochemical properties of aidan and turkey berry

The final physicochemical characteristics of aidan fruit (*Tetrapleura tetraptera*) and turkey berries are significantly influenced by their processing methods. Different techniques, such as drying and pretreatment, can affect these fruits in various ways. To maintain nutritional content and quality while enhancing efficiency, it is crucial to comprehend these effects and optimize the processing conditions accordingly. For turkey berries, a combination of abrasion and blanching pretreatment yielded the shortest drying time and preserved 36% of the vitamin C content (Barathiraja et al., 2022).This method also yielded the highest drying rate, maximum effective moisture diffusivity, and volumetric shrinkage ratio. Color changes were influenced by the chosen drying method, with untreated samples showing the most significant changes in color and chroma (Barathiraja et al., 2022).Aidan fruit (*Tetrapleura tetraptera*) undergoes significant changes in physicochemical properties during the drying and milling processes.

Traditional sun drying (TSD) requires three consecutive sunny days, whereas rotary drum drying (RDD) achieves a moisture content of 12% in only 120 min.RDD, operating at 55°C with a centrifugation force of 129.7 × g, ensures quick and uniform drying while maintaining the physicochemical qualities of the fruit (Zainal Abidin et al., 2024).The chemical composition of the fruit is altered when it is processed into a powder and used as a vanilla substitute in cookies. As the proportion of aidan powder increased in the cookie formulations, most chemical contents improved significantly, except for carbohydrates and metabolizable energy. The addition of aidan powder influences moisture, protein, ash, fat, fiber, and mineral content (Olatoye et al., 2020).These results highlight the necessity of selecting appropriate processing techniques to maximize the quality and nutritional value of these fruits for various food industry applications.

Development of a functional food additive

The food industry is witnessing a growing trend in the creation of functional food additives, with a particular focus on plant-derived ingredients.

These additives are becoming increasingly popular due to their perceived health advantages, eco-friendliness, and consumer preference for natural components (Zang et al., 2023).Contemporary trends in functional food additives involve the use of plant-based ingredients to improve food products' shelf life, flavor, visual appeal, and consistency . There is a growing focus on developing additives that not only enhance food quality but also offer additional health benefits. For example, the incorporation of plant-derived bioactive compounds into foods and drinks is becoming more common (Pin & Daniel, 2023). The functional beverage sector is experiencing significant expansion, with producers incorporating elements such as vitamins, minerals, antioxidants, fibers, and probiotics (Ghoshal & Kansal, 2019).

Nevertheless, the development of plant-based additives faces several obstacles. A notable concern is the possibility of allergic reactions in certain individuals, although these are rare (Pin & Daniel, 2023). Furthermore, there are apprehensions regarding the safety and potential adverse effects of natural additives, necessitating more thorough research. Incorporating plant-based additives into food products often requires sophisticated processing techniques and research to ensure their effectiveness and stability. Although the development of functional food additives, particularly plant-based ones, shows considerable promise for enhancing food quality and health benefits, it also presents significant challenges. Future studies should concentrate on improving the bioavailability and functionality of active compounds, investigating new technologies such as nano systems, and addressing safety concerns (Pin & Daniel, 2023; Zang et al., 2023).The food industry must strike a balance between innovation and safety while maintaining consumer acceptance to successfully develop and market these innovative additives.

Globally, regulatory frameworks for functional food additives exhibit variations but generally aim to ensure both safety and efficacy. In the United States, Europe, and at the international level, the FDA, EFSA, and JECFA, respectively, oversee food additives .These organizations prioritize demonstrating the safety and legitimate purpose of additives, which include enhancing food preservation, nutritional content, functional characteristics, processing, and consumer appeal, while preventing consumer deception or concealment of food deterioration (Abedi-Firoozjah & Tavassoli, 2024). Ghana's ongoing development of Food-Based Dietary Guidelines (FBDGs) exemplifies its commitment to improving food safety and nutrition standards by promoting healthful diets and fostering a health-supportive food environment (Aryeetey & Ramos, 2022).

Stages of producing turkey berry and aidan fruit additive

Turkey berry, has been used in spice mixtures and functional drinks.(Golly et al., 2018)optimized a spice blend containing powdered turkey berry, ginger, and anchovy, focusing on the antioxidant properties and sensory qualities. In functional beverages, turkey berries are mixed with ginger and butterfly pea flowers to enhance their nutrition and taste (Anggriani et al., 2023).The authors utilized response surface methodology to determine the ideal ratios for the spice blend and experimented with different combinations of beverages to balance antioxidant activity and palatability (Anggriani et al., 2023).These studies highlight the potential of turkey berries to improve the nutritional content and flavor in various culinary applications.

Tetrapleura tetraptera, or aidan fruit, is used as a spice and herbal remedy in West Africa. Compounds were extracted from the seeds using hexane and ethanol to identify valuable secondary metabolites and antimicrobial properties. Phytochemical analysis revealed alkaloids, flavonoids, and tannins, which showed significant inhibition against bacteria such as *Staphylococcus aureus* and *Escherichia coli*, suggesting their potential as natural antimicrobial agents for food preservation or pharmaceuticals (Korang et al., 2023). The production process for both turkey berry and aidan fruit involves harvesting, processing (such as drying and powdering), and combining it with other ingredients.

Effect of turkey berry on physiochemical properties of composite products

Turkey berry, showed significant synergies when combined with other ingredients, enhancing both the antioxidant capacities and sensory qualities of the products. A study optimized a spice blend of turkey berry powder (TBP), ginger powder (GP), and anchovy powder (AP). Higher TBP and AP levels improved antioxidant and sensory qualities, while higher GP levels reduced them (Golly et al., 2018). The optimal blend was 193.676 g TBP, 2.577 g GP, and 53.747 g AP, resulting in favorable total phenolic content, aroma, and antioxidant power. Additionally, a functional beverage combining turkey berry, ginger, and butterfly pea flowers significantly affects physicochemical and organoleptic properties, including pH, total phenolic content, flavonoid content, antioxidants, color, aroma, taste, and preference (Anggriani et al., 2023). Another study found that a tea blend of 50% roselle, 25% ginger, and 25% turkey berry had optimal protein, calcium, iron, and copper levels with high sensory acceptability (Teye et al., 2017). These findings indicate that turkey berries can be effectively combined with various ingredients to create products with enhanced antioxidant properties and sensory appeal, offering the potential for innovative functional foods and beverages.

Regarding the sensory characteristics, TBP blends can enhance taste, texture, and appearance. The optimized turkey berry spice blend received high sensory scores (>7 of 9) for aroma, taste, and overall acceptability (Golly et al., 2018). In biscuit production, adding fruit powders, such as Saskatoon berry, improved the appearance and taste at 10-15% inclusion levels (Kolesárová et al., 2022). Drying techniques, blending proportions, and product types are likely to influence the stability. Evaluating microbial growth, moisture content, and sensory changes over time is essential for determining the optimal formulations and storage conditions to maximize shelf life for commercial viability (Golly et al., 2018).

Turkey berry, demonstrates potential as a functional food ingredient with significant health benefits, including immunomodulatory and hepatoprotective properties. In terms of future applications, turkey berry could be valuable in functional foods and nutraceuticals due to its health-enhancing properties. Its antimicrobial capabilities, particularly from silver nanoparticles derived from its extract, may introduce new food preservation methods. Research also highlights turkey berry's antioxidant properties and its use in functional beverages, where it enhances antioxidant content and sensory qualities when combined with ginger and butterfly pea flower (Anggriani et al., 2023).Additionally, turkey berry powder has shown commercial promise in spice blend formulations. However, current research gaps include the need for long-term safety studies and clinical trials, as well as an exploration of the mechanisms behind its health benefits, especially its antiasthmatic properties. While turkey berry exhibits substantial promise as a functional food additive, further research is necessary to fully understand its potential and ensure safe, effective use in food applications.

Effect of aidan fruit on physiochemical properties of composite products

Research indicates that the Aidan fruit (*Tetrapleura tetraptera*) significantly affects the physicochemical properties of composite products when used as a flavoring agent. Incorporating Aidan into food formulations enhances the nutritional value and sensory qualities because of its rich bioactive compounds, such as flavonoids, tannins, and saponins. Studies on vanilla-Aidan-flavored cookies have shown improvements in the chemical composition and sensory attributes with higher Aidan content (Olatoye et al., 2020).The addition of Aidan increased moisture (1.83-3.77%), crude protein (9.83-12.86%), ash (0.55-0.71%), fat (0.98-1.29%), and fiber (0.35-0.46%) in the cookies. The mineral content also increased, particularly for phosphorus, iron, and zinc. Sensory evaluations revealed high acceptability in terms of appearance, taste, aroma, crispness, and overall liking. These findings suggest that Aidan enhances nutritional profiles and organoleptic properties, indicating its potential as a valuable ingredient in functional foods with better nutritional value and consumer appeal. Further research could explore the health benefits and applications of other baked goods or food products.

The integration of Aidan fruit into composite products enhances nutritional value, mineral content, and sensory attributes. Its ability to improve physicochemical properties while maintaining stability makes it a promising ingredient in functional foods. Aidan's potential extends to various food products, including beverages, snacks, and dairy alternatives. Investigating the bioavailability and bioactivity of Aidan compounds in different food matrices could optimize their use in functional food development. Additionally, exploring the synergistic effects with other ingredients could lead to innovative products with enhanced health benefits and consumer appeal.

CHAPTER THREE

MATERIALS AND METHODS

Introduction

This chapter delves into the strategies utilized to accomplish the study's goals. It opens with an overview of the research design, detailing the population, the study area, and the sampling methods. Furthermore, it outlines the processes for data collection and analysis, providing a comprehensive understanding of the methodologies applied.

Study area

The experiment was carried out in the laboratory of the School of Agriculture at the University of Cape Coast and the Ghana Standards Authority (GSA). Physicochemical and phytochemical chemical properties of raw and formulated products from Aidan and turkey berries were determined at the laboratories of Teaching and Research Laboratory of the School of Agriculture, UCC, and Ghana Standard Authority (GSA) respectively. The sensory and overall acceptability of produced functional additive was carried out at the School of Agriculture, UCC.

Source of raw materials

Samples of Aidan and turkey berry fruit were purchased at the Abura market within Central region, Ghana. Purchased samples were cleaned by washing the turkey berries thoroughly with clean water and thorough cleaning of the aidan fruit was done with the use of a clean napkin. Cleaned samples were kept in cleaned containers at room temperature for further analysis.

Preparation of aidan and turkey berry powder

The preparation of turkey berry and aidan fruit powder was based on the protocol as described by (Regina et al., 2018; Teye et al., 2018) with a slight modification as illustrated in Figure 3.

The turkey berries were manually sorted to remove any damaged ones and categorized by size to ensure uniform drying. They were washed with deionized water to eliminate physical impurities before further processing. (Figure 1A). The samples were parboiled for 10 minutes and dried in a dehydrator (Food roaster; 345W;110V;50-60Hz) at an average temperature of 65 ^{O}C for 24 hours at the School of Agriculture Research laboratory, University of Cape Coast (Figure 1B). The choice of drying temperature and time was based on previous work. The dried turkey berry samples were ground into a fine powder with a particle size of 30 µm using a multipurpose grinder. The resulting powder was packed into zip-lock bags and stored at 22°C until further analysis (Figure 1C).

Figure 1: Preparation of Turkey Berry Powder

Similarly, fresh Aidan fruits were sorted and cleaned before cutting through with a sharp knife to break them into smaller sizes (Figure 2 A - B). The fruits were further sundried for 7 days, pounded to achieve a smaller size, sundried again for 7 days and finally milled using a multi-purpose grinder (Figure 2 C). The powdered samples were then bagged into zip lock bags (Figure 2 D) and stored at 24 ^{O}C till further analysis.

Figure 2: Preparation of Aidan fruit powder

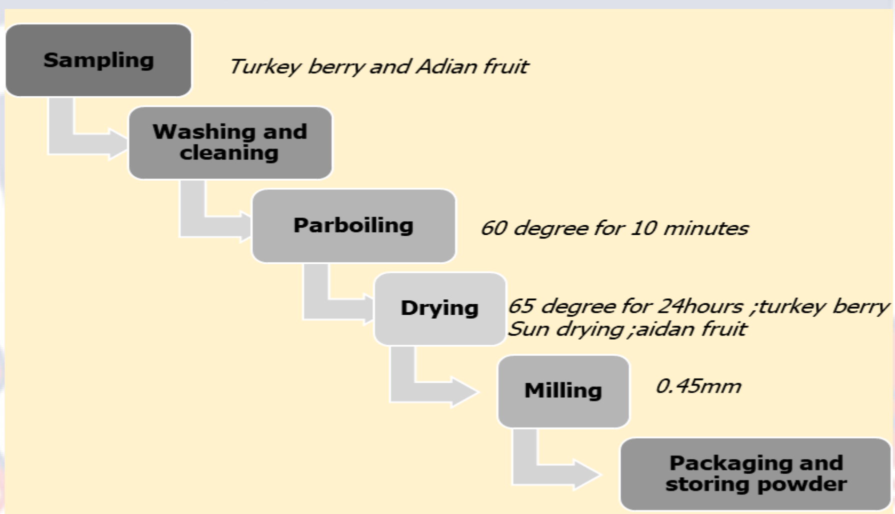

Figure 3: Turkey berry and Aidan fruit powder preparation protocol

Experimental Design and composite formulation

A completely randomized design with four (4) replications was used for the present study to assess the physicochemical and phytochemicals of raw and composite aidan and turkey berry additive. The actual levels of the independent variables are shown in Table 1. Absolute samples of aidan (100%) and turkey

(100%) powder served as the control samples in the present study. The other treatments comprised aidan and turkey berry in different blends as shown in Table 1.

The two ingredients (Turkey berry powder and Aidan fruit powder) were mixed into two main classes (Turkey berry: Aidan fruit) of composite powders were combined in the ratios outlined in Table 1 using an electric mixer set to speed 5 for 10 minutes to ensure a uniform blend, following the method employed by (Teye et al., 2018).

Table 1: Levels of independent variables of composite Turkey berry and Aidan fruit powder.

Sample	Turkey berry (%)	Aidan fruit (%)
T1	67.5	32.5
T2	60	40
T3	90	10
T4	75	25
T5	82.5	17.5
T6	50	50
T7	100	0
T8	0	100

Data collection

Proximate Composition Analysis

Physicochemical properties of the composite flours, including moisture content, protein, fat, ash, carbohydrate, fiber, and mineral elements such as sodium, potassium, phosphorus, calcium, magnesium, iron, zinc, and copper, were analyzed using standard methods with minor modifications. All measurements were conducted in triplicate (Gul & Safdar, 2009).

Moisture Determination

Porcelain crucibles were cleaned, dried, and weighed. Approximately 10–12 g of each sample was placed into clean, oven-dried crucibles, which were then reweighed. The crucibles with the samples were evenly distributed across the oven base to ensure uniform heat exposure. They were dried in a thermostatically controlled oven at 105°C for 48 hours. Afterward, the samples were removed, cooled in a desiccator, and weighed again. Each sample was processed in triplicate, and the moisture content was determined as the percentage of water lost by the sample.

Ash Determination

The dried samples were initially heated gently in the oven at 105°C for about an hour, then transferred to a furnace set at 550°C overnight. Heating continued until all carbon particles were fully burned off. The ash residue in the dish was removed from the furnace, cooled in a desiccator, and weighed. The ash content was then calculated as a percentage of the original sample.

Oil/ Fat Determination

Procedure

About 10- 12g of the milled samples were weighed into a 50 ×10mm Soxhlet extraction thimble. This was transferred to a 50ml capacity Soxhlet extractor. A clean dry 250ml round bottom flask was weighed. About 150ml Petroleum spirit was added and connected to the Soxhlet extractor and extraction was done for 6 hours using a heating mantle as a source of heating. After 6 hours, the flask was removed and placed in an oven at 60^{o}C for 2 hours. The round bottom flask was removed, cooled in a desiccator and weighed. The percentage of fat/oil was calculated as follows.

Calculation

Crude Fat (%) = $\frac{W\ (g) \times 100}{Sample\ (g)}$ Equ 1.

Where W is the Weight of the Oil

Protein Determination

The Kjeldahl method was used in the determination of protein. The method can be divided into three steps: digestion, neutralization or distillation and titration.

Digestion

Approximately 0.2 g of the sample was measured into a 100 mL Kjeldahl flask. Next, 4.4 mL of the digestion reagent was added, and the samples were digested at 360°C for two hours. A blank (prepared by digesting the reagent mixture without the sample) was processed in the same manner. After digestion, the resulting mixtures were quantitatively transferred into 100 mL volumetric flasks and diluted to the specified volume.

Distillation

A steam distillation apparatus was set up and rinsed with distilled water for about 20 minutes. Following this, 5 mL of boric acid indicator solution was poured into a 100 mL conical flask, which was positioned under the condenser, ensuring the condenser tip was fully submerged in the boric acid solution. An aliquot of the digested sample was introduced into the reaction chamber via the trap funnel, and 10 mL of an alkaline mixture was added to begin distillation. Approximately 50 mL of distillate was collected.

Titration

The distillate was titrated with a 0.1N HCl solution until the solution transitioned from green back to the original color of the indicator (wine red). Digestion blanks were subjected to the same process, and their values were subtracted from the sample titration readings. The resulting titration values were used to determine the nitrogen content, which was then converted to protein content using a conversion factor of 6.25.

$$\%\text{Total Nitrogen } (\%N) = \frac{(\text{Sample titre value} - \text{Blank titre value})\ X\ 0.1\ x 0.01401\ x\ 100}{sample\ weight\ X\ 10} \quad \text{Equ 2}$$

% Protein = %N x 6.25

Crude Fiber Determination

Procedure

Approximately 1 g of the sample was weighed and placed into a boiling flask, followed by the addition of 100 mL of 1.25% sulfuric acid solution. The mixture was boiled for 30 minutes. After boiling, the residue was filtered using a numbered sintered glass crucible. The residue was then returned to the boiling flask, and 100 mL of 1.25% sodium hydroxide solution was added and boiled for another 30 minutes. Filtration resumed after boiling, and the residue was washed thoroughly with boiling water and methanol. The crucible containing the residue was dried in an oven at 105°C overnight and weighed. It was then ashed in a furnace at 500°C for about 4 hours, gradually cooled to room temperature in a desiccator, and weighed again.

Calculation

$$\% \text{ Crude fiber} = \frac{\text{weight loss thro ashing}}{\text{Sample weight}} \times 100 \qquad \text{Equ 3}$$

(McCleary et al., 2013)

Total carbohydrate was determined by difference.

Preparation of Sample Solution for the Determination of K, Na, Ca, Mg, P, Zn, Cu & Fe

Preparing sample solutions for elemental analysis requires an oxidation process to break down organic matter. This is achieved through acid oxidation, which is essential for conducting a comprehensive elemental analysis.

Sulphuric Acid-Hydrogen Peroxide Digestion

The digestion mixture consisted of 350 mL of hydrogen peroxide, 0.42 g of selenium powder, 14 g of lithium sulfate, and 420 mL of sulfuric acid. According to the digestion procedure outlined by (Stewart, 1985), 0.1000 g to 0.2000 g of the oven-dried, ground sample was weighed into a 100 mL Kjeldahl flask. Then, 4.4 mL of the prepared digestion reagent was added, and the samples were digested at 360°C for two hours. Blank digestions, prepared by processing the digestion mixture without a sample, were carried out under the same conditions. After digestion, the resulting digests were quantitatively transferred into 100 mL volumetric flasks and diluted to the required volume.

Colorimetric Determination of P using the Ascorbic Acid Method

The procedure involves preparing color-forming reagents and phosphorus (P) standard solutions. The color-forming reagent consists of two components, Reagents A and B. Reagent A is prepared by dissolving 12 g of ammonium molybdate in 20 mL of distilled water, 0.2908 g of potassium antimony tartrate in 100 mL of distilled water, and mixing these with 1 L of 2.5M sulfuric acid (H_2SO_4). The three solutions are combined in a 2 L volumetric flask and diluted to the mark with distilled water (Dick & Tabatabai, 1977).

Reagent B was prepared by dissolving 1.56 g of ascorbic acid in every 200 mL of Reagent A. A stock solution containing 100 µgP/mL was prepared, from which a working standard series with concentrations of 0, 0.1, 0.2, 0.4, 0.6, 0.8, and 1.0 µgP/mL was created in 25 mL volumetric flasks. A 2 mL aliquot of each digested sample was pipetted into separate 25 mL volumetric flasks. Additionally, a 2 mL aliquot of the blank digest was added to each working standard to ensure the samples and standards shared the same background solution.

Ten milliliters (10 mL) of distilled water were added to both the standards and samples, followed by the addition of 4 mL of Reagent B. The volumes were then adjusted to 25 mL with distilled water and mixed thoroughly. The flasks were left to stand for 15 minutes to allow color development. After this, the absorbance of both the standards and samples was measured using a spectrophotometer at a wavelength of 882 nm. A calibration curve was plotted using the concentrations and corresponding absorbance values, and the concentrations of the sample solutions were determined by extrapolating from the standard curve.

Calculation

If C = μgP/mL obtained from the graph, then μgP/g (sample) = $Factor\ weight$

(Bianchi, 1985) Equ 4

Determination of Potassium and Sodium

Potassium and sodium in the digested samples were determined using a flame photometer. In the determination, the following working standards of both K and Na were prepared: 0, 2,4,6,8 and 10 μg/mL. The working standards as well as the sample solutions were aspirated individually into the flame photometer and their emissions (readings) were recorded. A calibration curve was plotted using the concentrations and emissions of the working standards. The concentrations of the sample solutions were extrapolated from the standard curve using their emissions .

Calculation

μgNa/g = $volume\ sample$ Equ 5

(Stewart, 1985)

Determination of Calcium and Magnesium By Edta Titration

The method involves the chelation of cations using ethylene diamine tetra-acetic acid (EDTA). It includes determining both calcium and magnesium together, followed by determining calcium alone and calculating magnesium by difference.

To determine calcium and magnesium together, 10 mL of the sample solution was placed in a 250 mL conical flask, and the solution was diluted to 150 mL with distilled water. Then, 15 mL of buffer solution and 1 mL each of potassium cyanide, hydroxylamine hydrochloride, potassium Ferro cyanide, and triethanolamine (TEA) were added. Five drops of Eriochrome Black T (EBT) were included, and the solution was titrated with 0.005M EDTA. For calcium determination, 10 mL of the sample solution was pipetted into a 250 mL conical flask and diluted to 150 mL with distilled water. Then, 1 mL each of potassium cyanide, hydroxylamine hydrochloride, potassium Ferro cyanide, and TEA were added, along with five drops of calcon indicator. The solution was titrated with 0.005M EDTA.

Calculations

$$\% \text{ Ca} = \frac{0.005 \text{ x } 40.08 \text{ x T}}{\text{Sample wt}} \qquad \text{Equ 6}$$

$$\% \text{ Mg} = \frac{0.005 \text{ x } 24.31 \text{ x T}}{\text{Sample wt}} \qquad \text{Equ 7}$$

Where T = titre value (Flaschka, 2013)

Determination of Iron, Copper and Zinc using Atomic Absorption Spectrophotometer

Standard solutions of 1, 2, and 5 µg/mL for Fe, Cu, and Zn were prepared. These standard solutions were introduced into the atomic absorption spectrophotometer (AAS), and the corresponding calibration curves were plotted. As the sample solutions were aspirated, their respective concentrations were determined. The concentrations were then calculated using the formula outlined by (Matthews-Amune et al., 2018).

Fe (μg/g) = $volume\ sample$

Cu (μg/g) = $volume\ sample$

Zn (μg/g) = $volume\ sample$

Phytochemical analysis of samples

Total saponins

For each sample, 2 g was weighed into a conical flask, and 10 mL of 20% aqueous ethanol was added. The mixture was heated in a water bath at approximately 55°C for 4 hours with continuous stirring. The mixture was then filtered, and the residue was re-extracted with an additional 20 mL of 20% ethanol. The combined extracts were concentrated in a water bath at about 90°C. The concentrate was transferred to a 250 mL separating funnel, and 10 mL of diethyl ether was added and shaken vigorously. The aqueous layer was collected, while the ether layer was discarded. The purification process was repeated, and 6 mL of n-butanol was added. The combined n-butanol extracts were washed twice with 1 mL of 5% aqueous sodium chloride. The residual solution was heated in a water bath, and after evaporation, the samples were dried in an oven to a constant weight. The saponin content was determined using a diosgenin standard curve after measuring the absorbance at 544 nm (Koomson et al., 2018).

Total alkaloids

A 1 g sample was placed in a 250 mL beaker and combined with 40 mL of 10% acetic acid in ethanol. The covered beaker was then placed aside for 4 h. Subsequently, the mixture was filtered and the resulting extract was reduced to one-quarter of its initial volume using a water bath. Concentrated ammonium hydroxide was gradually introduced into the extract until precipitation was complete. After allowing the solution to settle, the precipitate was collected, rinsed with dilute ammonium hydroxide, and re-filtered. The remaining residue, which was identified as an alkaloid, was dried and weighed.(Koomson et al., 2018).

Total flavonoids

Exactly 1g of the plant sample was extracted repeatedly with 10 ml of 80% aqueous methanol at room temperature. The whole solution was filtered through Whatman filter paper No 42 (125 mm). The filtrate was later transported into a container evaporated into dryness over a water bath and weighed to a constant weight.

Total phenol

The total phenolic content assay is based on the oxidation of all phenolic compounds in a sample by the Folin-Ciocalteu reagent. This reagent is a mixture of phosphotungstic acid ($H_3PW_{12}O_{40}$) and phosphomolybdic acid ($H_3PMo_{12}O_{40}$), which, after oxidation of the phenols, is reduced to a mixture of blue oxides of tungstate (W_8O_{23}) and molybdate (Mo_8O_{23}). The blue color produced has a maximum absorption at 750 nm and is directly proportional to the total amount of phenolic compounds present in the sample.

Procedure

Stock solutions of the ethanolic crude extract, methanolic, and hydro fractions were prepared by dissolving 10 mg of each dried sample in 1 mL of the respective solvent, followed by filtration.

Total Carotenoid

First, 2 g of the prepared product was measured and placed in a volumetric flask. Subsequently, 3 g of celite and 25 mL of acetone were added, and the components were blended to create a uniform paste. The resulting suspension, which contained the extracted carotenoid, was then transferred to a filter plate funnel connected to a 250 mL vacuum flask for filtration. The mixture was washed with acetone at least three times until the sample became colorless, indicating complete extraction. The carotenoid-rich acetone extract was then moved to a 500 mL extraction funnel containing approximately 40 mL of petroleum ether. To eliminate acetone, ultrapure water was gradually added to avoid emulsion formation. This resulted in the separation of two phases: (a) petroleum ether-containing carotenoids and (b) water mixed with acetone. The latter phase was discarded, and the separation procedure was repeated two or more times. A funnel lined with filter paper containing 3 g of anhydrous sodium sulfate was positioned on top of the volumetric flask. The entire carotenoid extract from the extraction funnel was then passed through this sulfate layer into a 50 mL flask. Quantification of carotenoid content in the extracts was performed using a spectrophotometer set to a wavelength of 450 nm, with petroleum ether serving as the blank. The total carotenoid content was determined using a specified formula:

Carotenoids (µg/g) =

A×V(mL)×104A1cm1%×P(g)\frac{A \times V (\text{mL}) \times 10^4}{A_{1cm}^{1\%} \times P (\text{g})}A1cm1%×P(g)A×V(mL)×104

Equ 8

Where; A = absorbance V = total volume of the extract (ml) P = weight of the sample (g) 1% 1cm A = 2592 – molar absorptivity coefficient of β-carotene (in the petroleum ether).

Sensory analysis

Instruments for Data Collection

The instrument for the data collection for the sensory evaluation of the new formulation was in two parts. The first part was Section A which focused on the biographical information of the respondent. The second, section B focused on collecting data on various sensory parameters and consumer acceptability characteristics of the formulated new product.

Data Collection Procedure

Taste panelists were used to collect data for sensory evaluation. A group of 75 panelist was given the opportunity to taste, smell, and feel each sample, as well as provide feedback on several aspects of the sample, such as appearance, taste, texture, odour, and general acceptability, using a -point hedonic scale questionnaire (Olawoye & Gbadamosi, 2020). The evaluation took place over two days in the University of Cape Coast, School of Agriculture Teaching and Research Laboratory, UCC (Figure 4).

Respondents' sensory and acceptability evaluation of single and composite aidan and turkey berry additive was collected using a structured questionnaire using a 9-point hedonic scale. Respondents were given the chance to try the product and express their hedonic opinion on various features of it by choosing and marking one of five options (range from 1 to 9). The structured questionnaire for responses is shown Appendix 1.

Figure 4: Pictures of panelist during sensory evaluation of formulated functional products

Ethical consideration

The Panellists that consumed the developed or formulated blends of the turkey berry and aidan fruit powder did give their personal data as part of the requirement for the study. At the onset of the data collection, measures were put in place to avoid biases and distortion of the data provided. The participants were briefed about the study after they have been selected using the appropriate sampling technique. When they agreed to be part, they were made to sign the consent form in duplicate. One was kept by the principal investigator and the other one-handed to the participant.

The participants were briefed about their rights and responsibilities in line with the study. Any of the participants had the right to withdraw from participating in the study at any stage of the study without prejudices.

Participation in the study was purely voluntarily. Hence, any participant withdrawing from the study did not incur any cost. All information provided was treated as confidential. The application was sent to the Department of Institutional Review Board for clearance. The clearance given was to guide how the data collection and ethical issues had to be handled to bridge any ethical issues. A copy of the clearance letter given is shown in Appendix B.

Statistical analysis

Statistical analysis of the physicochemical and sensory acceptability data was conducted using Analysis of Variance (ANOVA). When F-values were found to be significant ($p < 0.05$), the mean values were compared using Tukey's test at a significance level of 0.05. For descriptive sensory evaluation, ANOVA was performed on individual sensory attributes, with samples or formulations as the primary factor. The mean values were compared using Tukey's test ($p < 0.05$). All statistical analyses were performed using Statistical Package for Social Sciences (SPSS) version 23 and Genstats discovery edition 12.

CHAPTER FOUR

RESULTS AND DISCUSSION

Results

Objective 1: Evaluate the proximate, mineral composition and phytochemical composition of raw Aidan and turkey berry

Proximate composition of raw aidan and turkey berry

Moisture content

There was a significant variation ($p = 0.012$) in moisture content among fruit samples. Moisture content was relatively higher for turkey berry (8.23%) compared to aidan fruit which had moisture content of 5.66% (Table 2).

Ash

There was a significant variation ($p = 0.008$) in ash content among fruit samples. Ash content was relatively higher for turkey berry (3.27%) compared to aidan fruit which had an ash content of 1.97% (Table 1).

Protein

Raw fruit samples differed significantly ($p = 0.017$) in their protein content (Table 2). Protein ranged from 4.04 - 5.8 representing 1.4-fold variation between turkey berry and aidan fruit (Table 1).

Fats and Oil

Similarly, fats and oil were significantly different ($p < 0.001$) for fruit samples as illustrated in Table 1. Fats and oil were 27.7% higher for aidan fruit compared to turkey berry which had 5.27% fats content (Table 2).

Fibre

Analysis of variance (ANOVA) showed a significant variation (p = 0.005) in fibre content of samples (Table 2). Fibre content ranged from 4.62 - 12.9% for aidan and turkey berry fruit respectively.

Carbohydrate

No substantial variation (p = 0.19) was observed in carbohydrate content among samples. However, Aidan fruit had 5% increase in carbohydrate content compared to turkey berry fruit (Table 2).

pH

pH varied significantly (p = 0.003) among fruit samples. Aidan fruit had significantly higher pH of 5.64 compared to turkey berry which had the lowest pH of 5.07 (Table 2).

Table 2: Proximate composition of raw aidan and turkey berry fruit

	Proximate composition						
SAMPLES	**Moisture (%)**	**Ash (%)**	**Protein (%)**	**Oil/Fat (%)**	**Fibre (%)**	**CHO (%)**	**pH**
Aidan	5.66 **a**	1.97 **a**	4.04 **a**	6.73 **a**	4.62	64.21 **a**	5.64 **a**
Turkey berry	8.23 **b**	3.27 **b**	5.80 **b**	5.27 **b**	12.91	61.11 **a**	5.07 **b**
ANOVA							
p-value	*0.012*	*0.008*	*0.017*	*<0.001*	*0.005*	*0.190*	*0.003*
Lsd	*1.21*	*0.50*	*0.98*	*0.09*	*2.58*	*6.83*	*0.14*
CoV (%)	*5.00*	*5.40*	*5.70*	*0.40*	*8.40*	*3.10*	*0.70*

Mineral composition of raw aidan and turkey berry fruit

Sodium

Sodium content was significant ($p < 0.001$) among fruit samples. Turkey berry had 383.1 µg/g sodium concentration which was 47.9% higher compared to aidan fruit which had 259.1 µg/g (Table 2).

Potassium

Significant variation ($p = 0.002$) in potassium was observed among raw fruit samples. Potassium was 42.5% higher for turkey berry compared to aidan fruit which had 4700 µg/g (Table 3).

Phosphorus

ANOVA indicated an insignificant variation ($p = 0.064$) in phosphorus content among fruit samples. However, phosphorus concentration was 20.3% higher in turkey berry compared to aidan fruit (Table 3).

Calcium

Calcium content varied significantly ($p = 0.004$) among fruit sample. Calcium concentration ranged from 1.47 - 2.30% for aidan and turkey berry fruit respectively (Table 3).

Magnesium

Magnesium concentration was significantly higher in Turkey berry (2.32%) than in Aidan (1.41%), with a p-value of 0.008 (Table 2).

Iron

Turkey berry exhibited significantly (p = 0.022) higher iron concentrations compared to aidan fruit which had lower iron concentration of 70.92 µg/g (Table 2).

Zinc

Raw fruit samples differed significantly (p =0.025) in their zinc content (Table 2). Zinc ranged from 24.15 - 28.05 µg/g representing 1.6-fold variation between turkey berry and aidan fruit (Table 3).

Copper

Raw fruit samples differed significantly (p =0.002) in their zinc content (Table 2). Zinc ranged from 24.15 - 28.05 µg/g for aidan and turkey berry fruit respectively. Thus, copper was 15.5% higher for turkey berry compared to aidan fruit (Table 3).

Table 3: Mineral composition of raw aidan and turkey berry fruit

	Mineral composition							
SAMPLES	**Na (µg/g)**	**K (µg/g)**	**P (µg/g)**	**Ca (%)**	**Mg (%)**	**Fe (µg/g)**	**Zn (µg/g)**	**Cu (µg/g)**
Aidan	259.1 **a**	4700 **a**	2009 **a**	1.47 **a**	1.41 **a**	63.14 **a**	24.15 **a**	35.7 **a**
Turkey berry	383.1 **b**	6696 **b**	2416 **b**	2.30 **b**	2.32 **b**	70.92 **b**	28.05 **b**	41.27 **b**
ANOVA								
p-value	*0.001*	*0.002*	*0.064*	*0.004*	*0.008*	*0.022*	*0.025*	*0.002*
Lsd	*17.42*	*373*	*464.2*	*0.24*	*0.35*	*5.01*	*2.70*	*1.17*
CoV (%)	*1.5*	*1.9*	*6*	*3.6*	*5.3*	*2.1*	*2.9*	*0.9*

Phytochemical composition of raw aidan and turkey berry fruit

Table 4 illustrates the phytochemical composition of raw aidan and turkey berry fruit. Measured phytochemical properties including carotenoids, flavonoid, phenol and saponin varied significantly ($p < 0.001$) among raw aidan and turkey berry.

Carotenoid was 8.4% higher in aidan fruit compared to turkey berry which recorded the least mean carotenoid content of 117.4 µg/g (Table 4). Similarly, flavonoid was significantly higher for aidan fruit compared to turkey berry. Aidan fruit had a mean flavonoid of 31.7 mg /QE/100g compared to turkey berry which had 20.7 mg /QE/100g. Aidan fruit recorded 23.4% increase in phenol relative to turkey berry which had 77.3 mg/100g of phenol (Table 4). Conversely, turkey berry recorded saponin content of 6.34 mg/g which was 19.6% greater compared to 5.3 mg/g saponin content recorded by aidan fruit (Table 4).

Table 4: Phytochemical composition of raw aidan and turkey berry fruit

	Phytochemicals			
SAMPLES	**Carotenoids (µg/g)**	**Flavonoid (mg /QE/100g)**	**Phenol (mg/100g)**	**Saponin (mg/g)**
Aidan	127.3 **a**	31.68 **a**	95.4 **a**	5.3 **a**
Turkey berry	117.4 **b**	20.74 **b**	77.3 **b**	6.34 **b**
ANOVA				
p-value	*< 0.001*	*< 0.001*	*< 0.001*	*<0.001*
Lsd	*3.34*	*2.4*	*8.61*	*0.76*
CoV (%)	*1.2*	*3.2*	*2.7*	*4.3*

In column, the percentages affected by the same letter are not statistically significantly different at p< 0.05. Means with similar variables are insignificant whiles means with different variables are significant at 5% probability level

Objective 2: Determine the proximate and mineral composition of formulated aidan and turkey berry composite powder

Proximate composition of single and composite aidan and turkey berry powder

Moisture content

Significant ($p < 0.001$) was observed among single and composite aidan and turkey berry powder (Table 5). Moisture content ranged from 4.5 – 9.7% indicating double fold variation between the upper and lower boundaries. Among single powder, T(100):A(0) (6.1%) had relatively higher moisture content compared to T(0):A(100) (4.5 %) however, single powder had relatively lower moisture content compared to composite powder (Table 4). Among composite powder, moisture content was 19 – 116 % higher in T(90):A(0) compared to other samples. Similarly, T(82.5):A(17.5) had 15.8%, 19.2% and 20.9% increase in moisture content compared to T(75):A(25), T(67.5):A(32.5) and T(60):A(40) respectively. Conversely, moisture content was similar for samples including T(50):A(50), T(60):A(40) and T(67.5):A(32.5) despite variation in magnitude (Table 5).

Ash

Ash content of single and composite aidan and turkey berry powder differed significantly ($p < 0.001$) as illustrated in Table 5. The results indicated 2.8-fold variation in ash content among aidan and turkey berry powder samples. Ash content was relatively lower for single aidan (2.1%) and turkey berry (3.2%) powder samples. Among composite samples, an increasing trend in ash content was observed with increasing composition of turkey berry (Table 4). For example, sample T(90):A(10) record the highest ash content of 5.8% which was similar to T(82.5):A(17.5) (5.5%) but 11.7%, 17.3%, 20.4% and 27.3% higher compared to T(75):A(25) (5.2%), T(60):A(40) (4.9%), T(67.5):A(32.5) (4.8%) and T(50):A(50) (4.6%) respectively (Table 4). Non-significant variation was observed in ash content of samples T(60):A(40), T(67.5):A(32.5) and T(50):A(50). Similarly, ash content insignificant for sample T(75):A(25) and T(82.5):A(17.5) (Table 5).

Protein

Single and composite aidan and turkey berry powder varied significantly ($p < 0.001$) in protein content (Table 5). Protein content ranged from 6.6 – 12.9% for T(0):A(100) and T(90):A(10) respectively. A double-fold variation was observed in protein content among single and composite powder (Table 5). Protein content was relatively lower for single powder samples T(0):A(100) and T(100):A(0). Despite the observed variation, protein content was similar for T(60):A(40) (10.5%), T(67.5):32.5(10.6%), T50(50):A(50) (10.7%) and T(75):A(25) (11.6%). Conversely, sample T(90):A(10) (12.8%) recorded 10.6 – 95% increase in protein content compared to other samples (Table 5). Similarly, sample T(82.5):A(17.5) had 17.8%, 18.8% and 19.7% increase in protein compared T(50):A(50), T(67.5):A(32.5) and T(60):A(40) respectively (Table 5).

Fats and oil

Fats and oil among samples differed significantly ($p < 0.001$) (Table 5). Fats and oil ranged from 2.2 – 7.4% indicating 3.3-fold variation between upper and lower extremities (Table 4). Among single powder samples, fats and oil was relatively higher for T(100):A(0) which had 34% increase in fats and oil compared to T(0):A(100) which had 5.5%. An inverse trend in fats and oil was observed with increasing aidan fruit. Single powder samples had relatively higher fats and oil compare to composite samples. For example, a percentage increase of 69.9 – 234.9 was recorded in fats and oil among single ingredient powder compared to composite powder. Among composite powder, fats and oil was relatively higher for T(50):A(50) which had a mean fats and oil of 4.4% representing 32 – 49.2% increase compared to T(60):A(40) (3.3%), T(67.5):A(32.5) (2.3%), T(75):A(25) (2.3%), T(82.5):A(17.5) (2.2%) and T(90):A(10) (2.2%) (Table 5).

Fibre content

Single and composite powdered samples differed ($p < 0.001$) in their fibre content (Table 5). Similarly, fibre content increased with increasing turkey berry composition in the sample. Among single powdered samples, fibre content was relatively higher in T(100):A(0) compared to T(0):A(100) however, both samples recorded significantly lower fibre content relative to composite samples (Table 5). Fibre content was similar for T(90):A(10) (19.9%), T(82.5):A(17.5) (19.6%) and T(50):A(50) (19.3%) as well as for samples T(60):A(40) (16.1%) and T(75):A(25) (17.49%) (Table 5).

Carbohydrate

Carbohydrate content varied significantly ($p < 0.001$) among samples ranging from 51.3 – 63.9 %, thus representing a fold variation between samples

(Table 5). Composite samples had significantly lower carbohydrate content compared to single samples (Table 5). Thus, composition reduced carbohydrate content of samples. Carbohydrate was highest for sample T(100):A(0) (63.9%) followed by T(0):A(100) (61.5%), T(50):A(50) (59.6%), T(60):A(40) (58.7%), T(67.5):A(32.5) (56.8%), T(75):A(25) (53.2%), T(82.5):A(17.5) (51.9%) and T(90):A(10) (51.3%) in a decreasing order (Table 5).

pH

Similarly**,** pH showed a significant ($p < 0.001$) among single and composite sample (Table 4). About a fold variation was observed in pH among study samples. pH was relatively higher for T(100):A(0) (5.6) compared to T(0):A(100) (5.3). On the hand, pH was insignificant for T(0):A(100), T(67.5):A(32.5), T(60):A(40), T(50):A(50), T(75):A(25) and T(82.5):A(17.5) (Table 5).

Table 5: Proximate composition of formulated aidan and turkey berry composite powder

SAMPLES	Proximate composition: Moisture (%)	Ash (%)	Protein (%)	Oil/Fat (%)	Fibre (%)	CHO (%)	pH
T(0):A(100)	4.49 **a**	2.09 **a**	6.57 **a**	5.51 **d**	10.47 **a**	61.47 **c**	5.26 **a**
T(100):A(0)	6.10 **b**	3.18 **b**	7.37 **a**	7.40 **e**	12.03 **b**	63.93 **c**	5.64 **bc**
T(90):A(10)	9.70 **e**	5.79 **f**	12.87 **d**	2.21 **a**	19.87 **e**	51.33 **a**	5.71 **c**
T(82.5):A(17.5)	8.65 **d**	5.49 **ef**	12.58 **cd**	2.23 **a**	19.63 **e**	51.89 **ab**	5.45 **ab**
T(75):A(25)	8.38 **cd**	5.19 **cd**	11.63 **bc**	2.25 **a**	17.40 **d**	53.24 **ab**	5.38 **b**
T(67.5):A(32.5)	8.14 **cd**	4.81 **bc**	10.59 **b**	2.30 **b**	14.65 **b**	56.76 **abc**	5.35 **a**
T(60):A(40)	8.03 **c**	4.94 **cd**	10.51 **b**	3.30 **c**	16.13 **d**	58.72 **abd**	5.36 **a**
T(50):A(50)	7.83 **c**	4.55 **c**	10.68 **b**	4.36 **d**	19.32 **e**	59.93 **bc**	5.37 **a**
ANOVA							
p-value	*<0.001*	*<0.001*	*<0.001*	*<0.001*	*<0.001*	*<0.001*	*<0.001*
Lsd	*0.37*	*0.24*	*0.58*	*0.43*	*0.24*	*0.71*	*0.01*
CoV	*2.8*	*3*	*3*	*6.7*	*2.9*	*4.8*	*0.1*

In column, the percentages affected by the same letter are not statistically significantly different at p< 0.05. Means with similar variables are insignificant whiles means with different variables are significant at 5% probability level

Mineral composition of single and composite aidan and turkey berry powder

Sodium (Na)

Sodium content varied significantly ($p < 0.001$) among samples. Sodium ranged from 207.9 – 624.8 µg/g representing a double fold variation among study samples (Table 6). Single samples had relatively lower sodium content compared to composite samples. Among single samples, T(100):A(0) had a sodium content of 369.1 µg/g compared to T(0):A(100) which had 307.9 µg/g sodium (Table 5). On the other, sodium content was similar for samples T(50):A(50) (413.2 µg/g), T(60):A(40) (418.8 µg/g), T(67.5):A(32.5) (420 µg/g) and T(75):A(25) (423.5 µg/g). However, 47.5 – 102.9% increase in sodium content was recorded in sample T(82.5):A(17.5) and T(90):A(10) compared to the other samples (Table 6).

Potassium (K)

Potassium content varied significantly ($p < 0.001$) among formulated single and composite aidan and turkey berry powder. A 1.4-fold variation in potassium content was observed among formulated samples (Table 6). It was clear that, composite samples recorded relatively higher potassium compared to single samples (Table 6). A direct association in potassium content was observed with increasing concentration of turkey berry in the composition (Table 6). Potassium content was highest for T(90):A(10) (10073 µg/g) followed by T(82.5):A(17.5), T(67.5):A(32.5), T(75):A(25), T(60):A(40) and T(50):A(50) (Table 5).

Phosphorus (P)

Significant variation ($p < 0.001$) was observed in phosphorus content among samples (Table 5). However, phosphorus content recorded by samples T(67.5):A(32.5) and T(75):A(25) were similar. In general, composite powder had higher phosphorus content compared to single samples. An increasing trend in phosphorus content was recorded with increasing turkey berry composition (Table 6). Sample T(90):A(10) (5058 µg/g) had the highest phosphorus content which was 10 – 158% higher compared to the other samples. Phosphorus content was 4590 µg/g, 4111 µg/g, 4080 µg/g, 3872 µg/g and 3471 µg/g for T(82.5):A(17.5), T(75):A(25), T(67.5):A(32.5), T(60):A(40) and T(50):A(50) respectively (Table 6).

Calcium (Ca)

Calcium content varied significantly ($p < 0.001$) among prepared single and composite aidan and turkey berry powder (Table 6). In general, calcium content of composite samples increased with increasing composition of turkey berry (Table 5). Calcium content was relatively higher for T(100):A(0) (1.2%) compared to T(0):A(100) (1%) which has the lowest calcium content. Among composite powder samples, T(90):A(10) had a mean calcium content of 4.3% which was 20.3 - 142.7% higher compared to other composite samples. Similarly, sample T(82.5):A(17.5) had 16%, 22.9%, 41% and 101.7% increase in calcium content compared to T(75):A(25), T(67.5):A(32.5), T(60):A(40) and T(50):A(50) (Table 6).

Magnesium (Mg)

Single and composite powder prepared from aidan and turkey berry fruit exhibited significant variation ($p < 0.001$) in magnesium content as indicated in Table 6. Magnesium content ranged from 0.9 – 4.4% indicating 4.6-fold change between highest and lowest extremities (Table 6). Lowest magnesium content was recorded by T(0):A(100) compared to T(100):A(0). Among composite powder, a direct association in magnesium content was observed with increasing turkey berry content among samples. Typically sample T(90):A(10) had the highest magnesium content followed by T(82.5):A(17.5), T(75):A(25), T(67.5):A(32.5), T(60):A(40) and T(50):A(50) in a decreasing order (Table 6).

Iron (Fe)

Iron content among single and composite aidan and turkey berry powder was significantly different ($p < 0.001$) as illustrated in Table 6. In general, a direct association was observed between iron content and increasing turkey berry concentration. However, iron content was similar for samples T(90):A(10) and T(82.5):A(17.5) which had the highest iron content of 113.8 and 113 µg/g respectively. Compared to T(0):A(100), sample T(100):A(0) had 6.6% increase in iron content. Iron content was 106.48 µg/g, 104.38 µg/g, 102.62 µg/g and 97.84 µg/g for samples T(75):A(25), T(67.5):A(32.5), T(60):A(40) and T(50):A(50) respectively (Table 6).

Zinc (Zn)

Zinc content among single and composite aidan and turkey berry powder was significantly different ($p < 0.001$) as illustrated in Table 6. Zinc content ranged from 19.7 – 45.6 µg/g thus, 2.3-fold variation in zinc content among single and composite powder (Table 6). Zinc content was relatively higher for composite samples compared to single samples however, zinc content of T(100):A(0) (22.4 µg/g) was comparable to zinc content recorded by sample T(50):A(50) (24.5 µg/g) in the present study. On the other hand, zinc content was relatively lowest for T(0):A(100) (19.7 µg/g) compared to other samples. Similarly, zinc content was similar for samples T(67.5):A(32.5) and T(60):A(40) as well as T(75):A(25) and T(82.5):A(17.5). On the other extreme, T(90):A(10) had zinc content of 45.6 µg/g representing 30 – 86.5% increase compared to other composite samples (Table 6).

Copper (Cu)

Similarly, copper content among single and composite powder differed significantly (Table 6). Copper content was insignificant for sample T(67.5):A(32.5) (50.6 µg/g) and T(90):A(10) (51.4 µg/g) as well as T(50):A(50) (44 µg/g) and T(60):A(40) (46.7 µg/g) (Table 5). On the other hand, sample T(82.5):A(17.5) and T(75):A(25) had relatively higher copper content compared to the other samples (Table 6).

Table 6: Mineral composition of formulated Aidan and turkey berry composite powder

SAMPLES	Na (ug/g)	K (ug/g)	P (ug/g)	Ca (%)	Mg (%)	Fe (ug/g)	Zn (ug/g)	Cu (ug/g)
	Mineral composition							
T(0):A(100)	307.9 **a**	6979 **a**	1957 **a**	1.05 a	0.94 **a**	70.1 **a**	19.72 **a**	33.96 **a**
T(100):A(0)	369.1 **b**	7300 **a**	2188 **b**	1.41 **b**	1.43 **b**	74.7 **b**	22.43 **b**	39.37 **b**
T(90):A(10)	611.6 **d**	10073 **e**	5058 **g**	4.30 **g**	4.35 **g**	113.8 **g**	45.61 **e**	51.36 **f**
T(82.5):A(17.5)	624.8 **d**	9830 **e**	4590 **f**	3.57 **f**	3.62 **f**	113.0 **g**	35.04 **d**	63.33 **e**
T(75):A(25)	423.5 **c**	8872 **d**	4111 **e**	3.07 **e**	3.11 **e**	106.5 **f**	35.04 **d**	55.00 d
T(67.5):A(32.5)	420.0 **c**	9218 **cd**	4080 **e**	2.90 **e**	2.94 **e**	104.4 **e**	32.38 **c**	50.61 **d**
T(60):A(40)	418.8 **c**	8620 **bc**	3872 **d**	2.52 **d**	2.56 **d**	102.6 **d**	30.66 **c**	46.72 **c**
T(50):A(50)	413.2 **c**	8432 **b**	3471 **c**	1.77 **c**	1.79 **c**	97.8 **c**	24.45 **b**	44.02 **c**
ANOVA								
p-value	*<0.001*	*<0.001*	*<0.001*	*<0.001*	*<0.001*	*<0.001*	*<0.001*	*<0.001*
Lsd	*12.27*	*232.5*	*107.1*	*0.12*	*0.13*	*0.58*	*1.36*	*1.7*
CoV	*1.6*	*1.6*	*1.5*	*2.8*	*2.8*	*0.3*	*2.6*	*2.1*

In column, the percentages affected by the same letter are not statistically significantly different at p< 0.05. Means with similar variables are insignificant whiles means with different variables are significant at 5% probability level.

Objective 2: Determine the phytochemical composition of formulated aidan and turkey berry composite powder

Carotenoids

Carotenoids content among single and composite powder differed significantly ($p < 0.001$) as illustrated in Table 7. In general, carotenoid content of samples showed a positive association with increasing turkey berry content (Table 6). Carotenoid ranged from 133.6 – 219.8 µg/g representing 1.6-fold variation between samples. Among single component powder, T(100):A(0) had 142.6 µg/g carotenoid indicating 6.7% increase compared to T(0):A(100) which had the lowest carotenoid of 133.6 µg/g (Table 7). It was clear that composite samples had relatively higher carotenoids compared to single samples. Sample T(90):A(10) had a mean carotenoid of 219.8 µg/g which was 17 – 64.5% increase compared to T(82.5):A(17.5) (187.3 µg/g), T(75):A(25) (177.3 µg/g), T(67.5):A(32.5) (166.5 µg/g), T(60):A(40) (159.2 µg/g) and T(50):A(50) (148.9 µg/g) (Table 7).

Flavonoid

Similarly, flavonoid varied significantly ($p < 0.001$) among single and composite samples (Table 7). Flavonoid ranged from 2.5 – 69.9 mg QE/100g indicating 3.1-fold variation among samples. Flavonoid content exhibited a direct association with increasing content of aidan fruit in the composition. Sample T(0):A(100) had a mean flavonoid of 36.9 mg QE/100g compared to sample T(100):A(0) which had 22.5 mg QE/100g. Composite sample had higher flavonoid compared to single sample however, flavonoid recorded by T(0):A(100) was comparable to T(90):A(10) which had 40.3 mg QE/100g mean flavonoid (Table 6). On the other hand, T(50):A(50) (69.9 mg QE/100g) had the highest flavonoid content followed by T(60):A(40) (62.4 mg QE/100g), T(67.5):A(32.5) (54 mg QE/100g), T(75):A(25) (50.8 mg QE/100g) and T(82.5):A(17.5) (43.97 mg QE/100g) in a decreasing order (Table 7).

Phenol

Phenol content was significantly ($p < 0.001$) different among single and composite powder (Table 7). A 2.8-fold variation was recorded in phenol content between the upper and lower boundaries. Sample T(0):A(100) had 159.1 mg/100g content of phenol which was 62.8% higher compared to sample T(100):A(0) which had the lowest phenol content of 97.7 mg/100g (Table 6). Among composite samples, phenol content was similar for samples T(50):A(50) and T(60):A(40) as well as sample T(60):A(40) and T(67.5):A(32.5) (Table 6). On the other hand, phenol content differed among samples T(75):A(25) (230.5 mg/100g), T(82.5):A(17.5) (205.2 mg/100g) and T(90):A(10) (179.6 mg/100g) as well as compared to other samples (Table 7).

Saponin

Saponin ranged from 6.3 – 14.7 mg/g or samples T(0):A(100) and T(90):A(10) respectively. Thus, 2.3-fold change in saponin was observed between samples formulated in the present study (Table 7). A direct relation in saponin and increasing turkey berry content was observed in the present study. Saponin content was similar for T(90):A(10) and T(82.5):A(17.5) (14.3 mg/100g) which had relatively higher saponin content compared to other samples. Similarly, despite variation in saponin content among sample, saponin was relatively the same for samples T(50): A (50), T(67.5): A(32.5) and T(60): A(40) which had mean saponin ranging from 11.1 – 11.4 mg/100g (Table 7).

Table 7: Phytochemical composition of formulated Aidan and turkey berry composite powder

	Phytochemicals			
SAMPLES	**Carotenoids (µg/g)**	**Flavonoid (mg QE/100g)**	**Phenol (mg/100g)**	**Saponin (mg/g)**
T(100):A(0)	133.6 **a**	22.54 **a**	97.7 **a**	8.11 **a**
T(0):A(100)	142.6 **b**	36.9 **b**	159.1 **b**	6.3 **b**
T(50):A(50)	148.9 **c**	69.92 **f**	277.8 **g**	11.37 **c**
T(60):A(40)	159.2 **d**	62.37 **e**	265.9 **fg**	11.11 **c**
T(67.5):A(32.5)	166.5 **e**	54.04 **d**	251.1 **f**	11.24 **c**
T(75):A(25)	177.3 **f**	50.77 **d**	230.5 **e**	12.83 **d**
T(82.5):A(17.5)	187.3 **g**	43.97 **c**	205.2 **d**	14.29 **e**
T(90):A(10)	219.8 **h**	40.32 **bc**	179.6 **c**	14.73 **e**
ANOVA				
p-value	*< 0.001*	*< 0.001*	*< 0.001*	*<0.001*
Lsd	*3.34*	*2.4*	*8.61*	*0.76*
CoV	*1.2*	*3.2*	*2.7*	*4.3*

In column, the percentages affected by the same letter are not statistically significantly different at p< 0.05. Means with similar variables are insignificant whiles means with different variables are significant at 5% probability level

Objective 3: Evaluate sensory and overall acceptability of formulated aidan and turkey berry composite powder

Characteristics of respondents

Demographic characteristics of study panellist is presented in Table 8. The resulted that both males and females from diverse background were involved in the study. Female panellist was 57.1% compared to male panellist which were the minority with a percentage of 42.9%. Vast majority (52.9%) of panellist were within the 25-29 age bracket whereas 40%, 2.9%, 1.4% and 2.9% were within < 25, 30 - 34, 35 - 39 and > 40 age brackets respectively (Table 8). Additionally, majority of respondents were undergraduates with 14.3%, 25.7%, 7.1% and 45.7% been level 100, 200, 400 and 300 respectively. However, 7.1% were either PhD or Masters students (Table 8).

Table 8: Socio-demographic characteristics of panellist used for sensory and overall acceptability evaluation

Characteristics	Frequency (n)	Percentage (%)
Gender		
Female	40	57.1
Male	30	42.9
Age		
18 - 25	28	40
25 – 29	37	52.9
30 – 34	2	2.9
35 – 39	1	1.4
Above 40	2	2.9
Education		
PhD & Masters	5	7.1
Level 100	10	14.3
Level 200	18	25.7
Level 300	5	7.1
Level 400	32	45.7

Sensory evaluation and overall acceptability of samples

Appearance

ANOVA indicated a statistically significant difference in appearance ($p < 0.001$) among the samples (Table 9). A positive association was observed between appearance with increasing percentage of turkey berry in composition. Typically, appearance was relatively higher for T(90):A(10) and T(82.5):A(17.5) compared to samples T(67.5):A(32.5), T(50):A(50), T(60):A(40) and T(75):A(25) which had appearance score ranging from 4.7 – 6.4 (Table 9). Appearance was relatively lower for T(0):A(100) but comparable to scores by T(100):A(0) (4) (Table 9).

Aroma

There was a mark variation ($p < 0.001$) in aroma of formulated additive as rated by panellist in the present study (Table 9). There was not observable trend in aroma however, samples with higher composition of aidan fruit had highest aroma score. Example T(50):A(50) and (T60):A(40) had an aroma score ranging from 8 – 7.4 respective which were relatively higher compared to samples such as T(67.5):A(32.5), T(0):A(100) and T(90):A(10) which had a mean aroma score of 6 (Table 9). Unlike other parameters, T(0):A(100) had mean aroma score which was comparable to additives formulated from composite samples (Table 9).

Taste

ANOVA results ($p < 0.001$) indicated significant variations in taste across various formulated additives, with samples T(90):A(10) and T(82.5):A(17.5) recording the highest score of about 8 and 7.6 respectively compared other samples. Despite composite samples recording highest taste compared to single samples, taste recorded by additive produced from sample T(0):A(100) (4) and T(100):A(0) (4.1) were similar to taste score of 4.8 obtained by sample T(50):A(50) (Table 9).

Texture

A substantial variation ($p < 0.001$) was observed in texture among aidan and turkey berry additive. In the case of texture, sample T(90):A(10) (7.95) and T(82.5):A(17.5) (7.5) had the similar but highest texture score compared to samples T(75):A(25) (6.4) and T(67.5):A(32.5) (6.4) which as well had a similar score (Table 9). Texture score was relative equal for samples prepared from single aidan and turkey berry fruits. Compared to composite samples, texture score was relatively lower for single component additive samples (Table 9).

Overall Acceptability

ANOVA analysis revealed significant differences ($p = 0.003$) in overall acceptability among the samples (Table 9). The overall acceptability ratings ranged from 3.8 (T(0):A(100) to 7.6 (T(90):A(10), with a strong preference for samples containing a high proportion of turkey berry. Thus, composite samples had higher acceptability compare to single component samples (Table 9). Overall acceptability was similar for single component samples. On the other hand, the acceptability of samples T(90):A(10) and T(82.5):A(17.5) was rated liked extremely whereas samples such as T(50):A(50) and T(60):A(40) were rated liked slightly (Table 9)

Table 9: Sensory evaluation and overall acceptability of samples among panellist

	Sensory and acceptability attributes				
Sample	**Appearance**	**Aroma**	**Taste**	**Texture**	**Overall acceptability**
T(0):A(100)	3.9 **a**	6.1 **bc**	4 **a**	4 **a**	3.8 **a**
T(100):A(0)	4.0 **a**	4.5 **ab**	4.1 **a**	4.1 **a**	4 **a**
T(50):A(50)	4.7 **ab**	8 **d**	4.8 **b**	4.7 **ab**	4.6 **b**
T(60):A(40)	5.1 **b**	7.4 **d**	5.2 **bc**	5.2 **b**	4.9 **bc**
T(67.5):A(32.5)	6.4 **c**	6.2 **c**	6.4 **c**	6.4 **c**	6.6 **d**
T(75):A(25)	6.3 **c**	5.7 **bc**	6.5 **d**	6.4 **c**	5.4 **c**
T(82.5):A(17.5)	7.5 **d**	5.3 **ab**	7.6 **de**	7.5 **d**	7.1 **de**
T(90):A(10)	7.9 **d**	5.7 **bc**	8.0 **e**	8 **d**	7.6 **e**
ANOVA					
p-value	*<0.001*	*0.003*	*<0.001*	*<0.001*	*0.003*
lsd	*0.48*	*0.52*	*0.48*	*0.48*	*0.32*
CoV	*4.8*	*4.9*	*4.7*	*4.8*	*3.3*

In column, the percentages affected by the same letter are not statistically significantly different at p< 0.05. Means with similar variables are insignificant whiles means with different variables are significant at 5% probability level. 9-point hedonic scale (1- Dislike extremely 2- dislike very much 3- dislike moderately 4- dislike slightly 5- neither like nor dislike 6- like slightly 7- like moderately 8- like very much 9- like extremely)

Discussions

Significant variation in proximate composition of aidan and turkey berry fruit

The results reveal significant variations in the proximate, mineral and phytochemical composition of turkey berry and aidan fruit (Table 2 – 7), highlighting their unique characteristics and potential contributions to dietary diversity.

Moisture content was significantly higher in turkey berry compared to aidan fruit. This difference may influence the fruits' shelf life and storage requirements. Ash content, an indicator of mineral content, was significantly higher in turkey berry (3.27%) than in aidan fruit (1.97%). These values are comparable to or higher than those found in some commonly consumed fruits like bananas (0.8%) and grapes (0.5%) (Johnson & Brown, 2019), indicating that these indigenous fruits could be good sources of essential minerals. Protein content varied significantly between the fruits, with turkey berry containing 43.6% more protein than aidan fruit. The protein levels (4.04-5.8%) are notably higher than those typically found in most fruits, which generally contain less than 1% protein (Wilson et al., 2020). This suggests that these indigenous fruits could contribute significantly to protein intake, especially in regions where animal protein may be scarce.

Fat content was significantly higher in aidan fruit compared to turkey berry, with a 27.7% difference. The fat content of aidan fruit (6.73%) is relatively high for a fruit, comparable to that of avocados (14.66%) (Garcia & Lopez, 2017).

This high fat content could contribute to the fruit's energy density and potentially provide essential fatty acids, though further analysis of the fat composition would be necessary to confirm this. Fiber content showed substantial variation, with turkey berry containing nearly three times more fiber than aidan fruit. The high fiber content of turkey berry (12.9%) is particularly noteworthy, as it exceeds that of many commonly consumed high-fiber fruits like raspberries (6.5%) and pears (3.1%) (Thompson et al., 2021).

This suggests that turkey berry could be an excellent source of dietary fiber, potentially contributing to improved digestive health and satiety. Carbohydrate content did not vary significantly between the two fruits, although aidan fruit had a slightly higher content. The carbohydrate levels observed (69.66-73.21%) are higher than those typically found in many fruits, which often range from 10-20% (Davis & Miller, 2022). This high carbohydrate content suggests these fruits could be significant energy sources in local diets. The pH values of both fruits were in the acidic range, with aidan fruit being less acidic (pH 5.64) than turkey berry (pH 5.07). These pH levels are similar to those of many common fruits like strawberries (pH 3.0-3.5) and peaches (pH 3.3-4.0) (Anderson et al., 2019). The acidity could contribute to the fruits' flavor profiles and may also play a role in their preservation properties.

Significant variation in mineral composition of aidan and turkey berry fruit

The analysis of mineral content in turkey berry and aidan fruit reveals significant differences in their nutritional profiles, providing valuable insights into their potential dietary contributions. These findings align with previous studies on underutilized fruits, emphasizing their potential role in addressing micronutrient deficiencies and enhancing overall dietary quality (Deepa & Sharma, 2024). Turkey berry's high mineral content makes it comparable to other nutrient-dense functional foods such as: Moringa (*Moringa oleifera)*, known for its high calcium, magnesium, and iron content, widely used to combat malnutrition in developing regions (Gopalakrishnan et al., 2016). Sodium content was significantly higher in turkey berry (383.1 µg/g) compared to aidan fruit (259.1 µg/g), representing a 47.9% difference. This finding is particularly noteworthy as sodium plays a crucial role in maintaining fluid balance and nerve function. However, excessive sodium intake is associated with hypertension and cardiovascular diseases. Therefore, the higher sodium content in turkey berry should be considered when recommending its consumption, especially for individuals on sodium-restricted diets (Dharmarajan, 2021). Potassium levels were also significantly higher in turkey berry, with a 42.5% increase compared to aidan fruit (4700 µg/g). This is a positive attribute, as potassium is essential for various physiological processes, including muscle function and blood pressure regulation. The higher potassium content in turkey berry aligns with the recommendations for increased potassium intake to counteract the effects of high sodium consumption in modern diets (Godden, 2024).

While phosphorus content did not show statistically significant variation between the two fruits, turkey berry contained 20.3% more phosphorus than aidan fruit. Phosphorus is crucial for bone health and energy metabolism, making both fruits valuable sources of this mineral. Calcium concentrations varied significantly, with turkey berry (2.30%) containing more calcium than aidan fruit (1.47%). This difference is noteworthy, as calcium is essential for bone health, muscle function, and cellular signalling. The higher calcium content in turkey berry could make it a valuable addition to diets lacking in dairy products or for individuals at risk of calcium deficiency. Magnesium levels were significantly higher in turkey berry (2.32%) compared to aidan fruit (1.41%). This mineral is involved in numerous enzymatic reactions and is crucial for muscle and nerve function (Duffine & Volpe, 2013). The higher magnesium content in turkey berry could contribute to meeting daily magnesium requirements, which is particularly important given that magnesium deficiency is relatively common in many populations.

Iron concentrations were significantly higher in turkey berry compared to aidan fruit (70.92 μg/g). Iron is essential for oxygen transport and energy production, and its higher content in turkey berry could be beneficial, especially for individuals at risk of iron deficiency anaemia. Zinc content also differed significantly between the two fruits, with turkey berry containing 28.05 μg/g compared to aidan fruit's 24.15 μg/g. This 1.6-fold variation is important, as zinc plays a crucial role in immune function, wound healing, and DNA synthesis. Copper levels were 15.5% higher in turkey berry compared to aidan fruit. While copper is required in smaller amounts, it is essential for various physiological processes, including iron metabolism and connective tissue formation. These findings highlight the nutritional value of both turkey berry and aidan fruit, with turkey berry generally containing higher concentrations of essential minerals. This information can be valuable for dietary recommendations and food fortification strategies, especially in regions where these fruits are commonly consumed or where micronutrient deficiencies are prevalent.

Significant variation in phytochemical composition of aidan and turkey berry fruit

The phytochemical analysis of raw aidan and turkey berry fruits reveals significant differences in their bioactive compound profiles, highlighting the unique nutritional and potential health benefits of each fruit. Carotenoids and flavonoids, known for their antioxidant properties, were found to be significantly higher in aidan fruit compared to turkey berry. The 8.4% higher carotenoid content in aidan fruit suggests its potential as a valuable source of provitamin A and other health-promoting carotenoids. This finding aligns with previous studies on aidan fruit, which have reported high levels of carotenoids, particularly β-carotene (Adewusi and Alofe, 1996). The higher carotenoid content in aidan fruit compared to turkey berry indicates its potential superiority as a natural source of these compounds, which are crucial for maintaining eye health and boosting immune function.

The flavonoid content in aidan fruit was substantially higher than in turkey berry, with a difference of 11 mg QE/100g. This significant variation in flavonoid levels suggests that aidan fruit may offer enhanced antioxidant and anti-inflammatory benefits. Previous research on Solanum species, including turkey berry, has shown varying levels of flavonoids (Yang & Ojiewo, 2013).The higher flavonoid content in aidan fruit positions it as a potentially more potent source of these beneficial compounds, which have been associated with reduced risk of chronic diseases such as cardiovascular disorders and certain cancers (Kumar and Pandey, 2013). Phenolic compounds, another important class of antioxidants, were also found to be significantly higher in aidan fruit, with a 23.4% increase compared to turkey berry. This finding is consistent with studies on other underutilized fruits, which often reveal high phenolic content (López-Romero et al., 2022). The elevated phenol levels in aidan fruit suggest its potential as a rich source of natural antioxidants, which could be exploited for both nutritional and pharmaceutical applications.

Interestingly, turkey berry exhibited a higher saponin content, surpassing aidan fruit by 19.6%. Saponins are known for their diverse biological activities, including anti-inflammatory, anticancer, and cholesterol-lowering effects (Güçlü-Üstündağ & Mazza, 2007). The higher saponin content in turkey berry suggests its potential use in developing functional foods or nutraceuticals targeting specific health outcomes related to saponin activity. These findings contribute to the growing body of research on underutilized fruits and their potential as sources of bioactive compounds. The significant differences in phytochemical profiles between aidan and turkey berry underscore the importance of diversity in fruit consumption for optimal health benefits. Moreover, these results highlight the potential of these fruits as natural sources of antioxidants and other bioactive compounds, which could be valuable in the development of functional foods, nutraceuticals, and natural preservatives.

The higher levels of carotenoids, flavonoids, and phenols in aidan fruit suggest its potential superiority as an antioxidant-rich food source compared to turkey berry. However, the elevated saponin content in turkey berry indicates its unique potential for specific health applications. These distinct phytochemical profiles emphasize the complementary nature of these fruits and the importance of maintaining biodiversity in our food systems. Future research should focus on identifying specific compounds within each phytochemical class and evaluating their bioavailability and bioactivity in vivo. Additionally, investigating the effects of processing and storage on these phytochemicals would provide valuable insights for potential commercial applications. Comparative studies with other commonly consumed fruits would further elucidate the relative nutritional value of aidan and turkey berry in a broader context. In conclusion, this study provides valuable insights into the phytochemical composition of aidan and turkey berry fruits, highlighting their potential as rich sources of bioactive compounds. The findings underscore the importance of exploring and utilizing underutilized fruits as potential sources of natural antioxidants and health-promoting compounds, contributing to both nutritional diversity and the development of novel functional foods and nutraceuticals.

Composition improves phytochemicals in aidan and turkey berry additive

The results demonstrate a notable variation in saponin content across the different sample formulations, highlighting the significant impact of formulation composition on saponin content. A clear and strong positive correlation was identified between the turkey berry content and saponin levels in the samples, providing compelling evidence that turkey berry serves as a primary and substantial source of saponins in these formulations. The highest saponin contents were observed in samples such as T(90):A(10) and T(82.5):A(17.5), is particularly noteworthy as it indicates that formulations with higher proportions of turkey berry. This finding is consistent with previous studies that report abundant saponins in Solanum species, which contribute to their anti-diabetic, anti-hypertensive, and antimicrobial effects (Mungofa et al., 2022). This information could be crucial for researchers or manufacturers aiming to maximize saponin content in their products. Insignificant variation in saponin levels observed among certain samples suggests the possibility of a threshold effect or a non-linear relationship between turkey berry content and saponin levels within certain concentration ranges. This observation warrants further investigation to fully understand the dynamics of saponin accumulation in these formulations and could have important implications for optimizing product compositions. This finding further corroborates the conclusion that turkey berry is indeed the primary source of saponins in these formulations.

Significant variation in sensory and overall acceptability of Aidan fruit and turkey berry

The sensory evaluation of formulated aidan and turkey berry composite powders demonstrated significant variations in appearance, aroma, taste, texture, and overall acceptability. Composite formulations, notably T(90):A(10) and T(82.5):A(17.5), achieved the highest scores across all sensory attributes, reflecting a pronounced preference for blends with higher proportions of turkey berry. In contrast, single-component samples, T(0):A(100) and T(100):A(0), exhibited the lowest ratings, emphasizing the synergistic effect of combining aidan and turkey berry to enhance sensory qualities. These findings underscore the potential of these composite powders as functional food products with improved sensory profiles, supporting their feasibility for broader consumer acceptance and market application.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

The natural components used in functional food additives have gained significant attention in the food industry, reflecting consumers' increasing preference for healthier and more natural food options. This trend is fueled by concerns about synthetic additives and a greater emphasis on health and wellness (Pin & Daniel, 2023). These natural alternatives offer multiple health benefits and can substitute for synthetic ingredients, which are becoming less favored by consumers (Vilas-Boas et al., 2021). This research concentrated on creating a functional food additive using underutilized crops, specifically turkey berry and aidan fruit. The investigation examined the physicochemical, phytochemical, and sensory characteristics of various formulations, uncovering significant differences in their compositions.

Conclusion

1. The development of a functional food additive from single and composite gaidan and turkey berry was successful. The formulations combined the distinctive physicochemical, phytochemical and sensory properties of the fruits, yielding products with significant variations. The study demonstrated that composite formulations had higher scores for all analyzed parameters compared to single blends; for instance composite formulations, notably T(90):A(10) and T(82.5):A(17.5), achieved the

highest scores across all sensory attributes, reflecting a pronounced preference for blends with higher proportions of turkey berry.

2. Physicochemical analysis of formulated single and composite aidan fruit and turkey berry food additive revealed significant variation among the formulations. Turkey berry was identified as a mineral-dense ingredient, with higher levels of moisture, ash, protein, fiber, and essential minerals such as sodium, potassium, calcium, magnesium, and iron. Conversely, *aidan* fruit exhibited higher fat, carbohydrate, and pH levels. These findings highlight the nutritional value of both turkey berry and aidan fruit, addressing the ability of composite formulations to optimize the nutritional profiles of food products by balancing their attributes.
3. Carotenoids, phenols and flavonoids, known for their antioxidant properties, were found to be significantly higher in aidan fruit compared to turkey berry. Turkey berry, on the other hand, demonstrated a higher concentration of saponins, which are known for their health-promoting properties, with higher compositions found in samples such as T (90): A (10). The composite formulations synergistically combined these bioactive properties, enhancing their functional potential to mitigate oxidative stress and support overall health.
4. Turkey berry and aidan fruit composite formulations, particularly T (90): A z(10) and T (82.5): A (17.5), received the highest scores for appearance, taste, texture, and overall acceptability, indicating strong consumer preference. In contrast, single-component formulations, especially

T(0):A(100), received the lowest ratings, underscoring the advantage of blending the two fruits to enhance sensory qualities.

Recommendations

The following recommendation were made based on the results of the present study:

1. Investigate the effect of different processing parameters on the functional food additive produced.
2. Explore the potential use of turkey berries as a natural source of saponins for industrial applications
3. Investigate optimal storage conditions to maintain the nutritional quality of both fruits over extended periods.

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APPENDICES

SENSORY QUESTIONNAIRE

The series of questions in this questionnaire forms part of a research conducted in the Department of Agricultural Engineering, UCC to "DEVELOP A FUNCTIONAL FOOD ADDITIVE FROM UNDERUTILIZED CROPS; TURKEY BERRY AND AIDAN FRUIT". This study is entirely voluntary and all participants will remain anonymous. All information provided will be treated as confidential, and the results will be presented in such a way that no individual will be identified.

1. Age
   - ○ <20
   - ○ 20-40
   - ○ >40
2. Gender
   - ○ Male
   - ○ Female

Education

- ○ PhD & Masters
- ○ Level 100
- ○ Level 200
- ○ Level 300
- ○ Level 400

3. Have you tasted turkey berry before?
   - ○ Yes
   - ○ No

4. Have you tasted Aidan fruit before?

   ○ Yes

   ○ No

5. Have you tasted turkey berry before?

   ○ Yes

   ○ No

6. Direction: please evaluate the food product sample according to your personal preference using sensory characteristics.

1- Dislike extremely 2- dislike very much 3- dislike moderately 4- dislike slightly 5- neither like nor dislike 6- like slightly 7- like moderately 8- like very much 9- like extremely

Appearance: How good the sample is?

Texture: How smooth the sample is?

Aroma: smell or fragrance

Taste: the sweetness or bitterness of the turkey berry powder

Overall Acceptance: Combined effect of appearance, texture, taste, and aroma

Appendix A1: Sensory evaluation form for sensory exercise

Sample Code	Appearance	Aroma	Taste	Texture	Overall Acceptance
A					
B					
C					
D					
E					
F					
G					
H					