

FORMULATION OF FUNCTIONAL TEA USING PINEAPPLE PEEL, LEMON PEEL, MINT, AND GREEN TEA

SHEILLA ASIMIRE

S21B52/001

A DISSERTATION SUBMITTED TO THE FACULTY OF AGRICULTURAL SCIENCES IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF BACHELOR OF SCIENCE IN FOOD SCIENCE AND TECHNOLOGY OF UGANDA CHRISTIAN UNIVERSITY

April, 2025



**UGANDA CHRISTIAN
UNIVERSITY**

A Centre of Excellence in the Heart of Africa

ABSTRACT

This study addresses the challenges of food waste and nutritional deficiency by creating a functional tea from pineapple peels, lemon peels, mint, and tea. Fruit processing in Uganda generates a substantial amount of organic waste, with pineapple and lemon peels accounting for around 20-35% of the fruit weight which have bioactive compounds.

Using response surface methodology with a D-optimal mixture design, 12 experimental formulations were tested, varying proportions of pineapple peel powder, lemon peel powder, and mint, with green tea constant at 30%. Sensory evaluations by 30 panelists assessed appearance, aroma, taste, mouthfeel, and overall acceptability.

Results showed that higher pineapple peel powder ratios negatively affected the sensory attributes, while lemon peel powder addition was beneficial for taste and mint addition improved appearance and overall acceptance. The optimized tea blend containing 80% pineapple peel powder, 15% lemon peel powder, and 5% mint showed significantly higher polyphenol content and vitamin C content when compared with the control tea.

DECLARATION

I, ASIMIRE SHEILLA, hereby declare that this dissertation is my original work, has not been plagiarized, and has not been submitted to any other institution for any award.

SIGNATURE: 

DATE: 16th April 2025

APPROVAL

This Dissertation has been organised by ASIMIRE SHEILLA under my supervision and is now ready for submission to UGANDA CHRISTIAN UNIVERSITY for the award of BACHELOR OF SCIENCE IN FOOD SCIENCE AND TECHNOLOGY.

SIGNATURE: 

DATE: 16th April 2025

MS. PHIONAH AMUTUHAIRE

DEDICATION

I dedicate this dissertation to my beloved parents, whose unwavering support, encouragement, and love have been my greatest strength throughout this journey. To my sisters, for their constant motivation and belief in me, and to my dear friends, who have stood by my side, offering their support and inspiration. Your love and encouragement have made this achievement possible, and I am forever grateful.

ACKNOWLEDGEMENTS

I extend my deepest gratitude to my supervisor, Madam Phionah Amutuhaire, for her invaluable guidance, patience, and constructive feedback throughout this research. Your expertise and support have been instrumental in shaping this dissertation.

I am also grateful to Uganda Christian University and the Faculty of Agricultural Sciences for providing the necessary resources and a conducive learning environment for my research. Special appreciation goes to the food laboratory for granting access to research facilities and materials.

A heartfelt thank you to my parents and family for their unwavering encouragement and support throughout this journey. To my friends, thank you for your motivation, understanding, and belief in me during this challenging yet rewarding process.

Above all, I thank God for granting me the strength, knowledge, and perseverance to complete this dissertation successfully.

TABLE OF CONTENTS

ABSTRACT	ii
DECLARATION.....	iii
APPROVAL.....	iv
DEDICATION	v
ACKNOWLEDGEMENTS.....	vi
LIST OF TABLES.....	xii
LIST OF FIGURES.....	xiii
LIST OF ACRONYMS AND ABBREVIATIONS.....	xiv
CHAPTER ONE	1
1.0 INTRODUCTION.....	1
1.1 Background	1
1.2 Problem statement	1
1.3 Objectives	2
1.3.1 Main objective	2
1.3.2 Specific objectives	2
1.4 Research question and hypothesis.....	2
1.5 Rationale.....	3
1.6 Significance.....	3
1.7 Scope	4
1.8 Conceptual framework.....	4
CHAPTER TWO	6

2.0 LITERATURE REVIEW	6
2.1. Tea and its functional properties	6
2.2 Health benefits of functional tea	6
2.3. Green tea in functional tea formulations	8
2.4. Fruit by-products as functional ingredients	8
2.5. Lemon peel properties and applications	9
2.6. Pineapple peel properties and applications	10
2.7. Mint as a complementary ingredient	11
2.8. Mixture design in product optimization	12
2.9. Consumer acceptability and sensory evaluation	13
CHAPTER THREE	15
3.0 METHODOLOGY	15
3.1 Research design	15
3.2 Area of study	15
3.3 Sources of information	15
3.4 Population and sampling techniques	16
3.5 Variables definitions and measurements	16
3.5.1 Independent Variables	16
3.5.2 Dependent Variables and Indicators	17
3.5.3 Control Variables	17
3.6 Procedure for data collection	17
3.6.1 Sourcing of Raw Materials	17
3.6.2 Sample Preparation	17

3.6.3 Tea Preparation Protocol	18
3.6.4 Consumer acceptability.....	19
3.7 Data collection instruments and equipment	20
3.7.1 Sensory evaluation forms	20
3.7.2 Determination of total polyphenol content	20
3.7.3 Determination of Vitamin C	21
3.8 Quality/error control	22
3.9 Data processing and analysis	23
3.10 Ethical considerations	24
3.11 Methodological constraints	24
CHAPTER FOUR.....	25
4.0 DATA ANALYSIS, PRESENTATION AND INTERPRETATION OF FINDINGS	25
4.1 Response Surface Regression Analysis	25
4.1.1 Appearance.....	25
4.1.2 Aroma.....	26
4.1.3 Taste.....	26
4.1.4 Mouth Feel.....	26
4.1.5 Overall acceptability.....	27
4.2 Surface plots.....	27
4.2.1 Appearance against mint ratio and pineapple peel ratio.....	27
4.2.2 Mouth feel against mint ratio, pineapple peel ratio	28

4.2.3 Taste against lemon peel ratio, pineapple peel ratio	29
4.2.4 Overall acceptability against mint ratio, pineapple peel ratio.....	29
4.3 Overlay plots.	30
4.3.1 Pineapple peel ratio against lemon peel ratio.....	30
4.3.2 Pineapple peel ratio against mint ratio.....	31
4.3.3 Lemon peel ratio against mint ratio.....	33
4.4 Response optimization.	33
4.5 Nutrient analysis.....	33
CHAPTER FIVE.....	35
5.0 DISCUSSION OF FINDINGS.....	35
5.1 Effect of pineapple peel ratio on sensory attributes	35
5.2 Effect of lemon peel ratio on sensory attributes	35
5.3 Effect of mint ratio on sensory attributes.....	36
5.4 Nutrient analysis.....	37
5.4.1 Vitamin C	37
5.4.2 Total polyphenol.....	37
CHAPTER SIX.....	38
6.0 CONCLUSION AND RECOMMENDATIONS.....	38
6.1 Conclusion	38
6.2 Recommendations.....	38
REFERENCES	39
APPENDIX	45

Appendix A: ANOVA Tables for Sensory Attributes.....	45
Appendix 1: one way ANOVA table for appearance.....	45
Appendix 2: one way ANOVA table for aroma.....	45
A3. ANOVA Table for Taste.....	46
A4. ANOVA Table for Mouth Feel.....	46
A5. ANOVA Table for Overall Acceptability.....	47
Appendix B: Regression Coefficients.....	48
Appendix B1. Coded Coefficients for All Responses.....	48
Appendix C: Predicted Responses.....	49
Appendix D: Variable Ranges.....	49
APPENDIX E: Sensory ballots for consumer acceptability.....	50

LIST OF TABLES

Table 1: D-optimal mixture design showing the 12 different experimental runs' compositions	19
Table 2: Regression model equations for responses.....	25
Table 3: Amount of vitamin C in the optimised tea sample	33
Table 4: The total polyphenol content of the optimised tea formulation as compared to the control green tea.....	34

LIST OF FIGURES

Figure 1: A conceptual framework showing independent, dependent, control and mediating variables.	4
Figure 2: surface plot of appearance against mint ratio, pineapple peel ratio	27
Figure 3: Surface plot of mouth feel against mint ratio, pineapple peel ratio	28
Figure 4: surface plot of taste against lemon peel ratio, pineapple peel ratio	29
Figure 5: Surface plot of overall acceptability against mint ratio, pineapple peel ratio	29
Figure 6: An overlay plot of pineapple peel ratio against lemon peel ratio.....	30
Figure 7: An overlay plot of pineapple peel ratio against mint ratio	31
Figure 8: An overlay plot of lemon peel ratio against mint ratio.....	33
Figure 9: Peeling of pineapples before drying	51
Figure 10: Pineapple peels after drying	51
Figure 11: Pineapple peel powder after grinding.....	51

LIST OF ACRONYMS AND ABBREVIATIONS

ANOVA: Analysis of Variance

CI: Confidence Interval

DCPIP: 2, 6-Dichlorophenolindophenol

EGCG: Epigallocatechin Gallate

GAE: Gallic Acid Equivalents

HPLC: High-Performance Liquid Chromatography

ISO: International Organization for Standardization

RSM: Response Surface Methodology

SDGs: Sustainable Development Goals

SE: Standard Error

UCU: Uganda Christian University

UIRI: Uganda Industrial Research Institute

UV: Ultraviolet

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

In recent years, Tea is one of the world's most popular beverages. Among its varieties, green tea stands out due to its high content of polyphenols, mainly catechins (such as epigallocatechin gallate, EGCG) that have been linked to numerous health benefits such as reducing inflammation (P.N.R.J & R.D.S, 2023). Mint, a popular herb used in beverages and culinary applications, complements green tea by adding a refreshing aroma and flavor. Studies have shown that combining mint and green tea enhances the antioxidant activity of the blend, making it more effective in scavenging free radicals (Akshaya & Arivarasu, 2021). Functional teas have seen a rise in demand due to their potential health benefits. These teas offer solutions to modern consumer concerns, including improved digestion, enhanced immunity and reduced oxidative stress. Unlike regular teas, functional teas are enriched with added nutritional or medicinal value, which is why the global functional tea market is projected to grow by 6.4% annually through 2027. (P.N.R.J & R.D.S, 2023)

In Uganda, post-harvest losses are a significant challenge, with up to 50% of fruits wasted, and pineapple peels make up a substantial part of this loss. Despite this, by-products like pineapple and lemon peel are rich in antioxidants like polyphenols, vitamin C and other bioactive compounds. Lemon peels are also known for their immune and digestive boosting properties. These peels, often discarded as waste, present an opportunity to be repurposed as functional beverages, aligning with both sustainability goals and growing health trends.

1.2 Problem statement

Uganda's fruit processing industry generates a lot of organic waste, particularly pineapple and lemon peels, which are discarded despite their bioactive compounds.

This waste increases environmental challenges, contributing 2.8 million tonnes of annual food waste (40% of harvested produce) and greenhouse gas emissions from decomposition. Globally, 30% of food is wasted, showing the urgent need for sustainable solutions(Raji & Onu, 2017).

While pineapple and lemon peels hold potential for functional food applications, their integration into marketable products remains underexplored. There is also limited utilisation of pineapple peel alongside lemon peels and mint in a tea blend and scarce research on their combined sensory profiles (aroma, taste, colour, appearance, mouthfeel).

There is also a lack of food-based solutions to combat food waste while leveraging pineapple peels as a healthy ingredient. This study proposes repurposing those peels into a nutrient-rich functional tea.

1.3 Objectives

1.3.1 Main objective

To develop a functional tea that not only addresses the issue of food waste but also and provides health benefits, promoting both sustainability and well-being.

1.3.2 Specific objectives

1. To optimize the ingredient ratio of pineapple peel powder, lemon peel powder and mint with respect to consumer acceptability.
2. To determine the total polyphenol and vitamin C content of the optimized tea.

1.4 Research question and hypothesis

H₀: There is no relationship between consumer acceptability and the ratios of pineapple peel powder, lemon peel powder, and mint.

H₁: There is a relationship between consumer acceptability and the ratios of pineapple peel powder, lemon peel powder, and mint.

What is the total polyphenol and vitamin C content of the tea?

1.5 Rationale

This study addresses the urgent need to reduce food waste and promote sustainable tea consumption by reusing the discarded pineapple and lemon peels into a functional tea. The research helps to provide a strategy to mitigate environmental pollution while also providing health benefits to the consumer. The project also aligns with the UN Sustainable Development Goals (SDGs)-SDG12 (responsible consumption) by reducing waste and SDG3 (good health) by delivering targeted nutritional benefit (Lau et al., 2021). This study provides a scalable solution for industries and customers prioritising eco-friendly and nutrient-rich products(Matharu et al., 2018; Torres-León et al., 2018; Banerjee et al., 2017).

1.6 Significance

This study advances sustainability, functional food innovation, and public health by transforming fruit by-products into antioxidant-rich beverages. It supports global goals like SDG 12 (responsible consumption) and SDG 3 (good health), addressing food waste while promoting eco-friendly practices.(Lammi et al., 2023; Schiavone et al., 2022)

The findings offer evidence-based guidance for policymakers to integrate waste valorization into sustainability strategies. Researchers gain a methodological reference for developing functional foods from underutilized agricultural by-products. (Agócs et al., 2023; Vieira et al., 2021)

For entrepreneurs and the food industry, the study highlights cost-effective upcycling strategies that reduce production costs and tap into the growing functional foods market. (Sharma et al., 2021). Public health benefits include access to nutrient-dense products that may reduce risks of chronic diseases.(Dhandevi & Jeewon, 2015; Iriundo-DeHond et al., 2020)

By tackling local challenges in Uganda’s fruit industry, the study presents scalable solutions with global relevance. It bridges food science and sustainability, offering practical applications for waste reduction, health improvement, and economic growth.

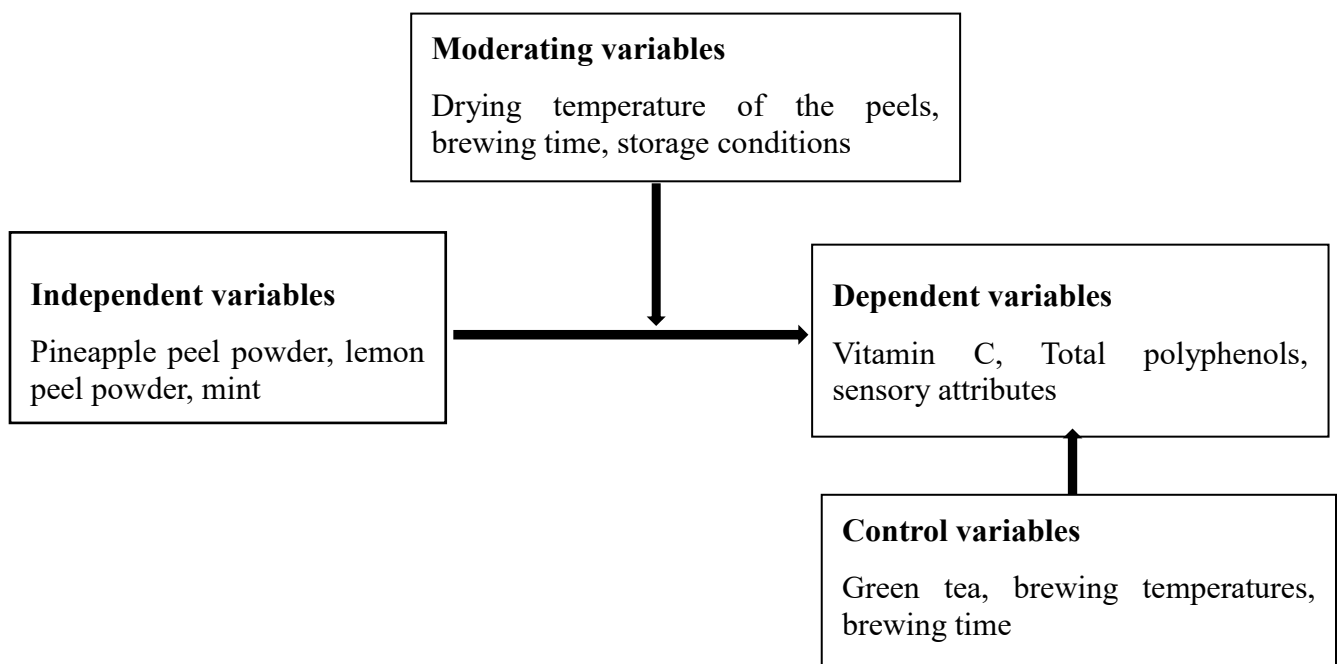
1.7 Scope

The study was conducted in Mukono, Uganda, at Uganda Christian University, Mukono campus. It focused on addressing local challenges in the fruit processing industry, particularly the utilisation of pineapple and lemon peels, which are abundant in Uganda. The experimental phase of the study spanned four months, from January 2025 to April 2025.

The research integrated aspects of food science and technology, incorporating elements from nutrition, chemistry, and sensory analysis to formulate and evaluate a functional tea blend.

1.8 Conceptual framework

Figure 1: A conceptual framework showing independent, dependent, control and moderating variables.



The proportion of pineapple peel powder, lemon peel powder, and mint directly affects the content of vitamin C, total polyphenol concentration, and sensory quality of the functional tea. Each ingredient contributes to the nutrient content and organoleptic quality, and their interactions determine the overall quality.

The green tea percentage was kept constant in all preparations to 30%, thus creating a control component that reduces the confounding effect of the different ingredients. The brewing temperature was also standardized to 85°C and the brewing time kept constant to 5 minutes in order to reduce the variability in processing as a source of confounding that influences the extraction of bioactive compounds and sensory properties.

Pre-processing conditions of the ingredients, like the temperature of drying fruit peels, the conditions during storage, and brewing methods, serves as mediators between the independent ingredients and the dependent variables. Even though these mediators were controlled to differentiate the effects of ingredient proportions, these are known to play crucial roles in product formulation.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1. Tea and its functional properties

Tea, the world's second most popular drink after water, is very culturally important and is liked for its sensory properties as well as for its bioactive ingredients (Khan & Mukhtar, 2019). The global tea market is \$214.7 billion as of 2023, led overwhelmingly by increasing demand for antioxidant-containing beverages (Petcu et al., 2023). Though numerous teas exist, black tea and green tea account for most of the world's tea production at approximately 98% (Çakmak et al., 2024).

Functional properties of tea arise primarily from its polyphenol content, mainly catechins (Musial et al., 2020). These compounds have potent antioxidant activities by various mechanisms of action, including metal chelation, antioxidant activity, and enzyme modulation. A study by Khan and Mukhtar (2019) noted considerable differences in the concentration and level of bioactive compounds in various types of teas and also in their production processes, pointing out the need for standardisation of research on functional teas.

More recent research has progressed towards optimised mixtures with complementary ingredients as well as specific functional effects (Pérez-Burillo et al., 2021). A study by Li et al. (2023), for instance, found that supplementation of vitamin C in green tea polyphenols improved catechin bioavailability by 30-45%, indicating its worth in combined formulations with complementary components of different bioactivity profiles.

2.2 Health benefits of functional tea

Pineapple Powder contains bromelain, a mixture of proteolytic enzymes with significant anti-inflammatory and digestive properties (Rathnavelu et al., 2016). Research demonstrates that bromelain effectively inhibits pro-inflammatory cytokines, aids protein digestion, and improves nutrient absorption (Muhammad et al., 2017). Clinical

studies confirm its efficacy in reducing joint pain in osteoarthritis patients and post-operative swelling (Kasemsuk et al., 2016). Additionally, bromelain's fibrinolytic activity may reduce platelet aggregation and blood clot formation, potentially lowering cardiovascular disease risk (Chakraborty et al., 2021; Sahbaz et al., 2015).

Lemon provides a rich source of vitamin C, citric acid, and various flavonoids including hesperidin, diosmin, and eriocitrin (Klimek-Szczykutowicz et al., 2020). These compounds exhibit potent antioxidant capacity, protecting cells against oxidative damage and age-related stress (Rasheed & Thajuddin, 2020). The high vitamin C content strengthens immune response by supporting neutrophil function, lymphocyte proliferation, and antibody production (Carr & Maggini, 2017). Citrus flavonoids demonstrate hypocholesterolemic and anti-atherogenic effects, contributing to cardiovascular protection through reduced LDL oxidation and improved endothelial function (Mahmoud et al., 2019; Testai & Calderone, 2017). Lemon also contains antimicrobial compounds effective against various pathogenic bacteria (Oikeh et al., 2020).

Mint contains menthol, menthone, limonene, cineole, and polyphenolic compounds that contribute to its diverse therapeutic properties (Mahendran & Rahman, 2020). Clinical trials demonstrate mint's effectiveness in managing irritable bowel syndrome symptoms through smooth muscle relaxation, reducing abdominal pain, bloating, and digestive discomfort (Alammar et al., 2019; Chumpitazi et al., 2018). The menthol component provides respiratory benefits, acting as a decongestant by inhibiting sensitivity to irritants (Eccles et al., 2015). Mint's aromatherapeutic properties show positive effects on cognitive performance, alertness, and memory through central nervous system stimulation (Meamarbashi, 2023). Additionally, mint exhibits broad-spectrum antimicrobial activity against oral pathogens, contributing to improved oral health and reduced dental plaque formation (Salehi et al., 2018; Fang et al., 2021).

The combination of these ingredients in functional tea formulations potentially enhances their benefits through synergistic interactions between bioactive compounds

(Basu et al., 2018). Polyphenols from tea can enhance the stability and absorption of vitamin C from lemon, while bromelain's proteolytic activity may increase the bioavailability of certain flavonoids (Williamson & Clifford, 2017), creating a functional beverage with comprehensive health-promoting properties targeting digestive, immune, cardiovascular, and cognitive systems.

2.3. Green tea in functional tea formulations

Green tea is the best base for manufacturing functional drinks due to its antioxidant effects, consumer acceptability, and versatile flavour profile that allows for the addition of other ingredients (Reygaert, 2018). Unlike black and oolong tea varieties, green tea undergoes minimal oxidation in steam or dry heat processing, leading to high concentrations of catechins, specifically epigallocatechin gallate (EGCG). This particular compound has the strongest antioxidant and anti-inflammatory activities among the different catechins found in tea (Musial et al., 2020).

Beyond the baseline benefits of green tea, recent research has explored synergistic interactions between green tea and other bioactive ingredients, offering further opportunities for enhancing its benefits. A study by Zhou et al. (2020) illustrated that the intake of green tea along with vitamin C-containing ingredients increased the absorption of catechins by about 25-30%. This effect was attributed to the reduction in the oxidation of catechins within the intestinal environment and enhanced stability during digestion. The findings suggest that citrus-based compounds may not only boost vitamin C levels but also enhance green tea catechin bioavailability through protection.

2.4. Fruit by-products as functional ingredients

Fruit processing by-products represent an underutilised resource with significant potential for transformation into functional ingredients. This approach aligns with the principles of the circular economy and sustainable food systems (Kumar et al., 2021). Fruits processing worldwide generates about 50 million tons of waste annually, while peels, seeds, and pomace typically account for 25-30% of the weight of the fruits themselves (Sharma et al., 2021). In Uganda specifically, fruit processing generates

substantial organic waste, with approximately 2.8 million tonnes of annual food waste representing 40% of harvested produce going unused (Raji & Onu, 2017).

Incorporating fruit processing waste into various food formulations offers dual benefits, such as reducing waste and enhancing functional properties. For example, a study by Melgar et al. (2022) stated that incorporating 10-15% fruit processing waste retained between 70-85% of the beneficial compounds in the fruits and tasted fine. A study by Oliveira et al. (2021) established that too high waste content occasioned issues such as irregular extraction, excessive clouding, as well as undesirable bitter flavours whenever the content exceeded 20%. This comparison illustrates the need for improved processing technologies to address such issues.

Fruit residues can be quite different depending on the fruit as well as how they are processed. This is difficult, but it is also an opportunity for the provision of health drinks. A study by Rodrigues et al. (2022) explains that peels of citrus contain 3-5 times as much flavonoid as the flesh of the fruit, whereas peels of pineapple contain 2-3 times as much bromelain as what is edible. O'Shea et al. (2022) found that standard drying decreased these valuable compounds between 40-60%. This implies that we should discover ways of retaining these precious qualities better.

2.5. Lemon peel properties and applications

Lemon peels (*Citrus limon*) are a common by-product of food processing that have a lot of potential for useful uses. According to González-Molina et al. (2016), these peels make up 25-30% of the fruit's weight and have higher flavonoid concentrations than the pulp. Hesperidin and eriocitrin are two to three per cent essential oils found in lemon peels, with limonene accounting for 60-75% of the total.

With reported levels of 50-70 mg/100g in fresh peels, lemon peels significantly contribute vitamin C to tea formulations (Sharma et al., 2017). Processing techniques, however, have a big influence on vitamin C retention. Putnik et al. (2021) showed that while controlled low-temperature drying (40-50 °C) preserved 65-80% of the vitamin C

content, traditional hot air drying at temperatures above 70°C decreased it by 60-75% in unique material. This comparison emphasises how crucial it is to use the right processing methods to maximise the functional advantages of the finished product.

From a sensory point of view, Palermo et al. (2020) found that while higher concentrations of lemon peel added excessive bitterness from flavanones and limonoids, low concentrations (0.5-1.5% w/v) of lemon peel improved the overall acceptability of herbal teas through contributions to citrus aroma. According to their sensory analysis, the best levels of incorporation rely on particular formulation objectives, and concentrations that strike a balance between functional advantages and sensory appeal yield the highest levels of consumer acceptance.

2.6. Pineapple peel properties and applications

With peels making 20-35% of the fruit weight, pineapple processing produces significant by-products (Campos et al., 2020). Thanks to their special bioactive profile and possible health advantages, recent studies have defined these peels as interesting functional components.

Against earlier presumptions of low nutritional value, compositional analyses by Patil and Kamble (2020) showed that pineapple peels include notable bioactive compounds, including bromelain (0.8-1.2% dry weight) and several phenolic compounds. With reported levels of 20-35 mg/100g fresh weight (Campos et al., 2020), pineapple peels add modest but notable vitamin C content.

A study by Li et al. (2021) found unidentified phenolic compounds in pineapple peels, including ferulic acid (15-25 mg/100g), p-coumaric acid (8-14 mg/100g), and several hydroxycinnamic acid derivatives that significantly increase antioxidant capacity. Their investigation highlights the need to maintain these molecules during processing to maximise functional advantages.

Compared to other fruit by-products, the bromelain content in pineapple peels offers a unique practical benefit. Clinically, this proteolytic enzyme complex has shown anti-

inflammatory effects (Kumar et al., 2021). But a study by Campos et al. (2023) noted a significant processing difficulty when bromelain activity dropped by 70-80% under traditional tea brewing temperatures (85-95°C for 3-5 minutes). By contrast, modified extraction at lower temperatures—60-70°C for 15-20 minutes—retained 60-75% of bromelain activity while still extracting 80-85% of phenolic compounds. This finding suggests that conventional tea preparation methods may require modification for maximising the functional benefits from pineapple peel components.

The use of pineapple peels in tea blends, along with other useful ingredients like lemon peels and mint, is still underexplored despite these encouraging qualities. Despite the possibility of improved functional qualities, a study by Thompson et al. (2022) identified a specific research gap concerning the combined sensory profiles and consumer acceptability of such multi-ingredient formulations.

2.7. Mint as a complementary ingredient

Mint (*Mentha* species) serves a number of roles in the formulation of teas, including a characteristic aroma, a corresponding flavour, and other bioactive substances (Mahboubi, 2021). Beyond its sensory attributes, mint also imparts notable functional properties that can further enhance the characteristics of tea and fruit by-products.

Recent phytochemical analysis by Nayak et al. (2021) reported that mint consists of 1.2-3.9% essential oils with a prevalence of menthol (30-55%) and menthone (14-32%), along with high levels of rosmarinic acid (0.8-2.5%) and other phenolic substances with proven antioxidant activity. These components are responsible for both sensory quality and functional value of mint-based products.

Mint has a key role in masking potentially undesirable flavour notes imparted by other functional ingredients. A study by Kamiloglu et al. (2020) demonstrated mint addition at 5-8% levels as successfully improving consumer acceptability of functional teas containing bitter ingredients, with controlled sensory analysis showing major improvements in overall palatability without compromising bioactive compound

extraction. This capacity of mint to blend with the senses makes it highly valuable where food by-products are incorporated into formulations, as these may have challenging flavour profiles.

In terms of bioactive stability, the extraction and stability profile of phenolic compounds in mint differ greatly from those in tea and citrus fruit peels. A study by McKay and Blumberg (2016) indicated that rosmarinic acid from mint exhibited better stability under neutral to slightly acidic conditions (pH. 5-7) than catechins from green tea, with possible protective effects when in formulated mixtures. This distinct stability profile can help to preserve bioactive substances during both processing and storage periods.

2.8. Mixture design in product optimisation

Mixture design is a branch of response surface methodology that is applied for the optimisation of formulations in foods, since final product characteristics are controlled by relative ingredient ratios rather than their total amounts (Gacula, 2008). Compared to standard experimental designs, mixture designs account for the constraint that the proportions of ingredients sum up to 100%, making them very suitable for the development of formulations in drinks, where ingredient interactions significantly impact final product traits.

Advancements in methodologies in the recent past have increasingly promoted the use of mixture designs in functional foods' formulations. Zhang et al. (2022) utilised the D-optimum mixture design in optimising a multi-component functional drink, illustrating its capability in pinpointing near-optimum formulations with fewer experimental runs relative to the standard full factorial designs. Their findings revealed non-linear ingredient interactions that could perhaps have been missed through the use of one-factor-at-a-time methodologies, hence highlighting the efficacy of using the mixture design methodologies in handling complex formulations.

In the development of tea-infused drinks, mix designs are quite effective in attaining the optimal balance between bioactive compounds and sensory acceptance. Research by Wan et al. (2020) applied the simplex-centroid mix design in optimising a functional green tea-based beverage, determining the optimal proportions of additional ingredients for increasing overall polyphenol content in line with consumers' preferences. Their model reached predictive precision of polyphenol content at 92% as well as sensory scores at 87%, demonstrating the effectiveness of this approach in formulating optimal teas.

One of the major strengths of mixture design is its ability to optimise multiple response variables simultaneously. Granato et al. (2018) reported on a multi-response optimisation method for designing functional drinks, where sensory acceptability, contents of bioactive compounds, and physical stability were evaluated simultaneously. Their approach utilised desirability functions for the determination of formulations with an optimal balance between these conflicting aims, thus providing a systematic approach for tackling the inevitable trade-offs in functional drink development. This is an improvement on previous optimisation protocols with their focus on one response variable at a time.

2.9. Consumer acceptability and sensory evaluation

Acceptance among consumers is an important determinant of functional drinks' success, requiring an optimal balance between bioactive ingredient delivery and sensory appeal (Jaeger et al., 2018). Recent studies have deepened our knowledge of how formulation factors interact with consumer response, hence presenting important insights for optimisation strategies

Consumer acceptance of functional teas is greatly determined by the target market segment. A study by Jaeger et al. (2018) found three distinct consumer segments related to functional drinks: health prioritizers, who value functional benefits over sensory qualities; sensory seekers, who enjoy both enjoyable tastes and functional benefits; and "traditionalists," who prefer familiar sensory qualities regardless of any

functional improvements that may enhance them. This segmentation suggests that optimisation efforts will differ by intended consumer segment, resulting in products that may be expressly tailored to specific market segments.

Offering functional benefits is essential in measuring consumer acceptance levels. A study by Meyners et al. (2021) established that transparent information about functional ingredients enhanced acceptability of novel sensory attributes by 25-35% among environmentally motivated consumers. Such evidence suggests that label transparency about upcycled ingredients, as well as benefits thereof, can enhance market acceptability of products with food by-products.

Optimization strategies based on consumer input have demonstrated better market performance than those based on expert-based formulations. Research by Wan et al. (2020) compared consumer feedback-optimized formulations with trained sensory panel-optimized formulations and found that the former achieved 15-20% higher purchase intent scores in later market tests. This result demonstrates that the inclusion of consumer opinions in the optimization process, rather than relying solely on analytical measures or expert opinion, increases the market potential of functional drinks.

In a research by Elemo et al. (2022), they concluded that sensory attributes like aroma, flavor, color, visual appearance, and texture significantly affected consumer acceptability of new ingredients, such as fruit peels. Their research highlighted the need for systematic improvement of such attributes during the development of functional drinks that contain unknown ingredients, particularly when blending different by-products that have distinct sensory profiles.

CHAPTER THREE

3.0 METHODOLOGY

3.1 Research design

The research employs a D-optimal mixture design under response surface methodology (RSM). Mixture designs are suited for experiments where independent variables are components of a mixture, and in this experiment, these are the tea ingredients, whose proportions must sum up to 100%. The D-optimal design was used because it reduces the number of experimental runs and captures the quadratic and interaction effects between ingredients. The D-optimal design was used because it excels in scenarios where ingredient proportions are restricted, which applies to this research.

3.2 Area of study

The study was conducted at the Faculty of Agricultural sciences in the Food Science Laboratory at Uganda Christian University- Mukono Campus. This facility offered the required equipment and controlled environments to carry out both ingredient preparation and sensory evaluation of the formulated tea. Mukono District is located in Central Uganda approximately 27 kilometres East of Kampala and at an elevation of 1158 to 1219 metres above sea level.

Nutrient analysis was carried out at two laboratories, that is, Makerere University Food Science Laboratory, accredited (ISO/IEC 17025:2017) for polyphenol analysis using Folin-Ciocalteu assays and Uganda Industrial Research Institute (UIRI), certified (UNBS ISO 9001:2015) for vitamin C quantification via titration.

3.3 Sources of information

Primary Data was derived from experimental measurements of total polyphenol, vitamin C content, and sensory evaluations conducted with untrained panellists. These evaluations assessed the acceptability of the tea based on sensory characteristics such as appearance, color, aroma, taste, and mouth feel.

Secondary Data included all materials that guided the experimental procedures, analytical methods, and formulation processes. Sources include literature on functional tea formulations, total polyphenol and vitamin C measurement techniques, and best practices in sensory evaluation and consumer testing. Standard guidelines for tea production and preservation also informed the methods used in this study.

3.4 Population and sampling techniques

The population consisted frequent tea consumers from the UCU campus, that is, students. A simple random sampling procedure was used in enrolling participants from the campus population of tea consumers. Out of the available pool of appropriate candidates who were regular tea consumers, 30 participants were randomly sampled for sensory evaluation.

The process of random selection guaranteed that all the eligible students had an equal probability of being selected to take part in the study, minimizing selection bias. This guaranteed a fair representation of the UCU tea-drinking student population.

A diverse sample was used in a bid to gain a wide representation of taste, and the participants were from varying age groups, genders, and regions. Participants were screened prior to involvement to confirm that they were regular tea consumers and devoid of any recognized taste disorder or tea ingredient allergy that would impact sensory evaluation scores.

3.5 Variables definitions and measurements

3.5.1 Independent Variables

Proportion of Pineapple Peel Powder: Measured as the percentage weight of pineapple peel powder in the tea blend.

Proportion of Lemon Peel Powder: Measured as the percentage weight of lemon peel powder in the tea blend.

Proportion of Mint: Measured as the percentage weight of mint leaves in the tea blend.

3.5.2 Dependent Variables and Indicators

Vitamin C content: measured in mg/100g (milligrams per 100 grams)

Total polyphenol content: measured in mg GAE/100g (milligrams of gallic acid equivalents per 100 grams).

Sensory Scores: Rated on a 9-point hedonic scale, representing the degree of like or dislike, evaluating taste, aroma, appearance, and mouthfeel.

3.5.3 Control Variables

Preparation Conditions: Pineapple peel was dried at 60°C for 48 hours, and lemon peel was dried at 60°C for 48 hours

Infusion Conditions: The tea was brewed at a temperature of 85°C and steeped for 5 minutes. The ratio of tea blend to water was 2 grams of tea per 200 ml of water.

All formulations consisted of 30% green tea.

3.6 Procedure for data collection

3.6.1 Sourcing of raw materials

Fresh pineapples and lemons were sourced from the same supplier from Mukono Market while dry mint and green tea of the same batch numbers were purchased from the supermarket. Upon receipt, all raw materials were thoroughly inspected for quality.

3.6.2 Sample preparation

The fruits were thoroughly washed to ensure hygienic conditions and prevent contamination of the final product. Both pineapples and lemons were scrubbed and dipped in warm water containing 0.05% sodium metabisulphite to eliminate surface microbes.

Fresh Pineapples were peeled, and the peels were arranged in a single layer on trays and dried in a convection air oven at 60°C for 48 hours. After drying, the peels were ground using a laboratory grinder and then passed through a fine mesh sieve to obtain a uniform powder. The resulting pineapple peel powder was stored in airtight containers and refrigerated at 18°C until further use.

Lemon peels were prepared using a similar procedure. After peeling, the lemon peels were spread evenly on trays and dried in a convection air oven at lower temperatures of 40°C for 48 hours to preserve volatile compounds. The dried peels were then ground using a laboratory grinder and sieved through a fine mesh sieve. The lemon peel powder was then stored in air-tight containers and refrigerated at 18°C.

3.6.3 Tea preparation protocol

Table 1 presents the tea formulations developed by combining pineapple peel powder, lemon peel powder, and mint, with green tea leaves maintained at a constant 30% of the total formulation. The experimental design used to optimize the blend of pineapple peel powder, lemon peel powder, and mint was a D-optimal design executed using Minitab software. The mixture variables were set as follows: pineapple peel powder varied between 80% and 90% w/w (± 0.001 g), lemon peel powder ranged from 5% to 15% w/w (± 0.001 g), and mint varied between 2% and 5% w/w (± 0.001 g). With the green tea held constant at 30%, the design generated a total of 12 runs.

Tea samples were prepared by steeping 2 grams of each blend in 200 ml of hot water at 85°C for 5 minutes. The brewed tea was then served to the panellists in plain, coded cups for evaluation.

Table 1: D-optimal mixture design showing the 12 different experimental runs' compositions

Run	Pineapple peel (%)	Lemon peel (%)	Mint (%)
1	90	5	5
2	86.5	10	3.5
3	83	15	2
4	88	10	2
5	81.5	15	3.5
6	93	5	2
7	91.5	5	3.5
8	80	15	5
9	93	5	2
10	85	10	5
11	82	13	5
12	83	15	2

3.6.4 Consumer acceptability

The twelve samples from the different runs were used for the consumer acceptance test. A hedonic test was performed using a nine-point scale where 1 represented extreme

dislike and 9 represented extreme like for the quality attributes for appearance, color, taste, mouthfeel, aroma and overall acceptability.

A total of 30 untrained panellists were used.

3.7 Data collection instruments and equipment

3.7.1 Sensory evaluation forms

Sensory evaluation was conducted using structured sensory evaluation forms, along with a 9-point hedonic scale, to assess the attributes of taste, aroma, and visual appeal in the tea formulations.

3.7.2 Determination of total polyphenol content

Total polyphenol content was determined using the Folin-Ciocalteu method, with absorbance readings taken using a UV-Visible spectrophotometer.

Sample Preparation: 0.5-1.0 grams of ground tea leaves or tea powder were accurately weighed and placed in a cleaned extraction container.

Extraction: 10 ml of 70% (v/v) aqueous methanol solution was added. The composite was subjected to a water bath at 70°C temperature for 30 minutes under continuous agitation to drive the extraction of the polyphenolic compounds.

Filtration: The extract was allowed to come to room temperature. Whatman No. 1 filter paper was used to filter the solution and obtain a clear extract.

Experimental Setup: 1.0 ml of the tea extract was transferred into a test tube or a cuvette. 5.0 ml Folin-Ciocalteu reagent, which was earlier diluted to 1:10 with distilled water, was added. 4.0 ml of 7.5% sodium carbonate solution (w/v) was added to the reaction mixture to neutralise the acidity and initiate the colour reaction. The mixture was thoroughly mixed.

Incubation: The reaction mixture was incubated for 30 minutes at room temperature with protection from sunlight to prevent degradation of the phenolic compounds.

Assessment: After the incubation time, the absorbance was measured at 765 nm using a calibrated UV-Visible spectrophotometer, against a reagent blank.

Measurement, Standard Curve Preparation: Gallic acid standards at known concentrations (0, 50, 100, 150, and 200 mg/L) were prepared using the same methodology in both reaction and measurement protocols.

Calculation: A standard calibration curve (absorbance vs. gallic acid concentration) was plotted. The polyphenol concentration in the sample extract was determined from the standard curve. Results were expressed as milligrams of gallic acid equivalents per gram of tea sample (mg GAE/g).

3.7.3 Determination of Vitamin C

Materials and Equipment: A Tea sample, analytical balance, volumetric flasks (100ml, 250ml), Erlenmeyer flasks (125ml), burette, beakers (600ml), graduated cylinder (500ml), pipettes, stirring rod, distilled water, and a heat source were assembled for the experiment.

Reagents Preparation: For the starch indicator solution, 0.50g of soluble starch was weighed and added to 50 ml of near-boiling distilled water. The mixture was stirred well and allowed to cool before use. For the iodine solution, 5.00g potassium iodide (KI) and 0.268g potassium iodate (KIO_3) were dissolved in 200 ml distilled water. 30 ml of 3M sulfuric acid was added. The solution was transferred to a 500ml graduated cylinder and diluted to the 500ml mark with distilled water. The solution was mixed well and labelled as Iodine Solution. For the vitamin C standard solution, 0.250g of ascorbic acid was dissolved in 100 ml distilled water, then diluted to 250 ml with distilled water in a volumetric flask. The solution was labelled as Vitamin C Standard Solution.

Standardisation of Iodine Solution: 25.00ml of Vitamin C Standard was pipetted into a 125ml Erlenmeyer flask. 10 drops of starch indicator solution were added. A burette was rinsed and filled with the iodine solution, and the initial volume was recorded. The solution was titrated while swirling until a blue-black colour persisted for 20 seconds. The final burette reading was recorded. The titration was repeated at least twice, ensuring results agreed within 0.1ml.

Titration of Tea Sample: A known volume (e.g., 25ml) of filtered tea sample was pipetted into a clean 125ml Erlenmeyer flask. 10 drops of starch indicator were added. The sample was titrated with iodine solution until a blue-black endpoint was observed. The initial and final volumes of iodine solution were recorded. The titration was repeated at least twice for accuracy.

Calculations: The average volume of iodine used (V) was calculated by dividing the sum of titrant volumes by the number of titrations. To determine the mass of vitamin C in the sample, a proportion was set up. From the standard, if 10.00ml iodine = 0.250g Vitamin C, then for the sample: $X = (V_{\text{sample}} \times 0.250\text{g})/10.00\text{ml}$. The concentration was converted by dividing X by the volume of the tea sample used. If the tea sample volume used was 25ml, then: Vitamin C concentration = $X/0.025\text{L}$ (in g/L).

3.8 Quality/error control

All raw materials were sourced from the same supplier to ensure consistency in quality and avoid variations in flavor profiles.

All equipment used was calibrated before each analysis to ensure precise and accurate readings.

Sensory evaluation samples were prepared in a separate area from the panellists and coded with random identifiers to avoid bias during the evaluation process.

All experiments were conducted under standardized conditions, including controlled brewing temperature, brewing time and drying temperature for fruit peels.

Data was validated using multiple statistical tools, with Statology for one sample t-test analysis, Stat-ease 360 used for response surface optimization and Minitab software employed for regression modelling.

3.9 Data processing and analysis

Descriptive statistics including means and standard deviations, were used to summarize the sensory scores evaluated by the panelists and the nutritional content. These measures gave an estimate of central tendencies and variability in the database.

To test the study hypothesis, inferential statistical methods were employed. Multiple linear regression analysis was used to model the relationships between the proportions of pineapple peel powder, lemon peel powder, and mint (independent variables), and the sensory and nutritional outcomes (dependent variables). This approach allowed for the identification of the most influential factors affecting consumer preference and product quality.

Analysis of Variance (ANOVA) was used to evaluate the significance of model terms, including linear, quadratic, and interaction effects. Regression coefficients—intercept, linear, interaction, and quadratic—were estimated using the least squares method. Multivariate linear regression with interaction terms was also employed, and model terms were refined through backwards elimination. Statistical significance was set at $p < 0.2$ to retain significant variables. The results were presented as means \pm standard error (SE).

Data analysis utilized Statology to analyze the one sample t-test in total polyphenol analysis, Stat-ease 360 for response surface methodology (RSM) to model ingredient interactions and Minitab for regression modeling and confirmation. These software packages delivered predictive models and optimized tea formulation based on sensory attributes.

3.10 Ethical considerations

All participants received detailed explanations of the study's purpose and procedures before providing informed consent. Participants' personal data and survey responses remained anonymous and confidential. Food safety protocols were strictly followed during tea preparation to ensure participant safety. Participants were informed of their right to withdraw from the study at any time without penalty. Waste generated from tea preparation was disposed of responsibly, aligning with sustainability principles.

3.11 Methodological constraints

The study was conducted in a controlled laboratory setting that may not fully mirror real-world production or consumer practices.

The study used a D-optimal mixture design with only twelve experimental runs, which limited the resolution for capturing complex interactions among pineapple peel, lemon peel, and mint, and constraints in visualization tools further hampered model interpretation.

The sensory evaluation relied on a localized purposive sample that may introduce bias and does not represent the broader demographic, while nutrient analysis faced challenges from thermal degradation during drying and the use of basic analytical methods that might not fully quantify bioactive compounds.

Additionally, the study's reliance on modeling assumptions that potentially oversimplify nonlinear interactions, along with unaddressed logistical challenges in sourcing, processing, and ensuring consistent quality of fruit by-products at scale, further limited its applicability.

The scope was confined to formulation optimization, nutrient analysis, and sensory evaluation without considering storage stability or long-term health impacts.

CHAPTER FOUR

4.0 DATA ANALYSIS, PRESENTATION AND INTERPRETATION OF FINDINGS

Table 2 shows regression models that examine the appearance, aroma, taste, mouthfeel, and overall acceptability attributes, thus demonstrating the quantitative relationships between ingredient ratios and sensory attributes. The models show the statistical significance of each formulation variable and enable the prediction of sensory outcomes based on the compositions of the ingredients..

Table 2: Regression model equations for responses

Response	Model equation	R ²
Appearance	$Y_1 = 6.450 - 0.267X_1^2 + 0.427X_3^2$	0.69
Aroma	$Y_2 = 72.5 - 1.486X_1 + 0.00830X_1^2$	0.5751
Taste	$Y_3 = 5.573 + 0.1491X_2 - 0.243X_1^2$	0.4599
Mouth feel	$Y_4 = 5.489 - 0.199X_1 - 0.242X_3^2$	0.3770
Overall acceptability	$Y_5 = 5.9000 - 0.2728X_1 + 0.256X_3^2$	0.7381

$X_1 = \text{Pineapple peel ratio}$, $X_2 = \text{Lemon peel ratio}$, $X_3 = \text{Mint ratio}$

4.1 Response Surface Regression Analysis

4.1.1 Appearance

The appearance model achieved an R-squared value of 69.20, indicating that approximately 69% of the variance in appearance scores can be explained by the model.

Pineapple peel ratio² (coefficient = -0.267): This negative quadratic effect indicates that appearance scores initially increase as pineapple peel ratio increases from lower levels, but then decrease at higher concentrations, forming an inverted U-shaped response.

Mint ratio² (coefficient = 0.427): This positive quadratic effect indicates that appearance scores are higher at either low or high mint concentrations, with lower scores in the middle range, forming a U-shaped response

4.1.2 Aroma

The aroma model showed an R-squared value of 57.51, indicating a moderate fit.

Pineapple peel ratio (coefficient = -0.3252): This negative linear effect indicates that aroma scores decrease as pineapple peel ratio increases.

Pineapple peel ratio² (coefficient = 0.351): This positive quadratic effect indicates that the relationship is not purely linear but has some curvature.

4.1.3 Taste

The taste model showed an R-squared value of 45.99, indicating a weaker fit compared to appearance and aroma.

Lemon peel ratio (coefficient = 0.1491): This positive linear effect indicates that taste scores increase as lemon peel ratio increases.

Pineapple peel ratio² (coefficient = -0.243): This negative quadratic effect indicates an inverted U-shaped response to pineapple peel ratio, though the effect is only marginally significant.

4.1.4 Mouth Feel

The mouth feel model showed the weakest fit with an R-squared value of 37.70%

Pineapple peel ratio (coefficient = -0.199): This negative linear effect indicates that mouth feel scores decrease as pineapple peel ratio increases.

Mint ratio² (coefficient = -0.242): This negative quadratic effect indicates an inverted U-shaped response to mint ratio.

4.1.5 Overall acceptability

The overall acceptability model showed the strongest fit with an R-squared value of 73.81%

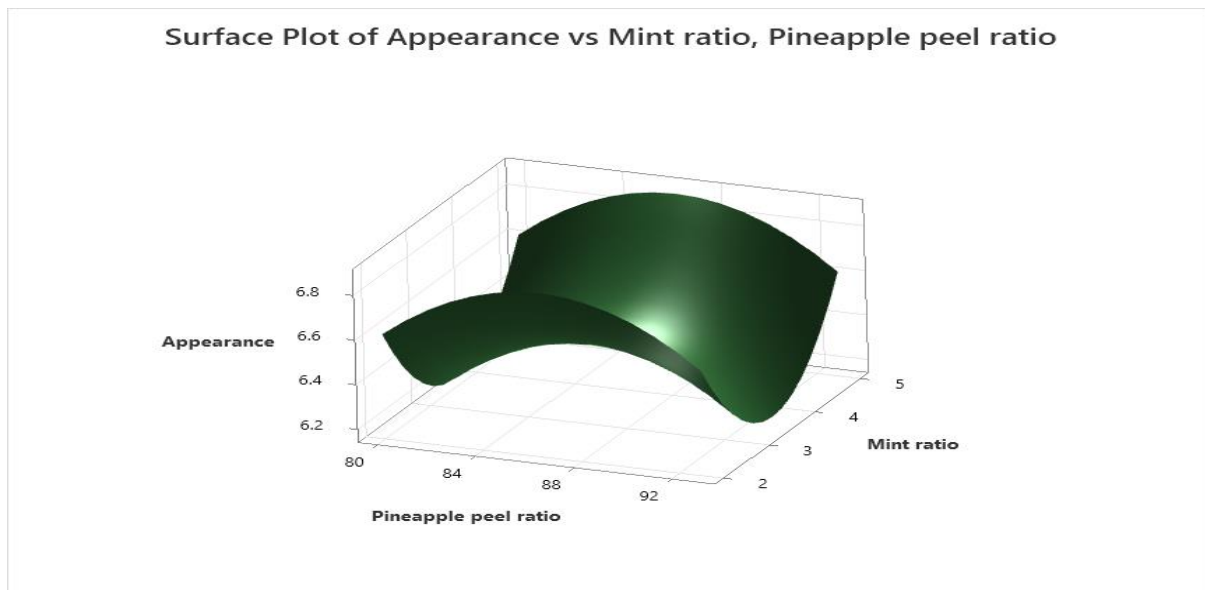
Pineapple peel ratio (coefficient = -0.2728): This strong negative linear effect indicates that overall acceptability scores decrease significantly as pineapple peel ratio increases.

Mint ratio² (coefficient = 0.256): This positive quadratic effect indicates a U-shaped response to mint ratio.

4.2 Surface plots

4.2.1 Appearance against mint ratio and pineapple peel ratio

Figure 2: surface plot of appearance against mint ratio, pineapple peel ratio



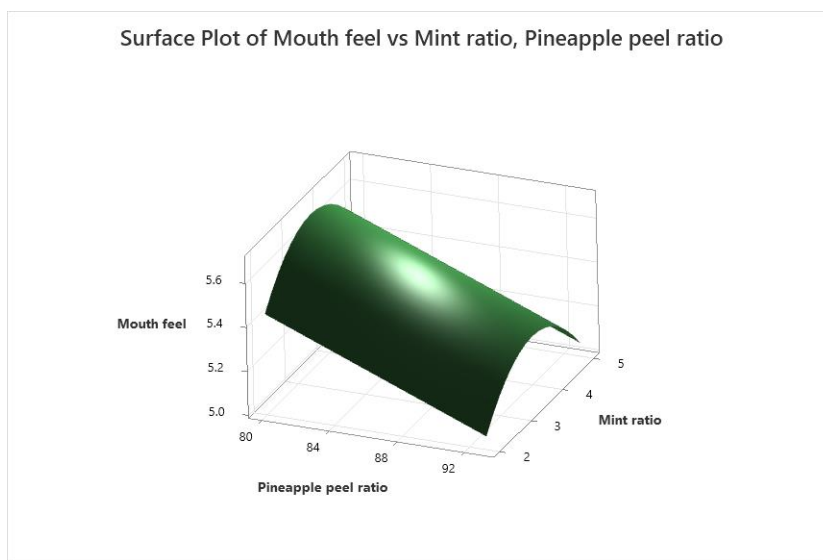
There's a U-shaped response curve for mint ratio, with appearance declining from mint ratios of 1-3%, then increasing as the mint ratio increases from 3-5%

For the pineapple peel ratio, there's a negative quadratic effect where appearance scores decrease as the pineapple peel ratio increases from 80% toward 90%

The highest appearance scores occur at lower pineapple peel ratios (around 80%) combined with either low (1%) or high (5%) mint ratios. These observations confirm the statistical findings of a positive quadratic effect for the mint ratio and a negative quadratic effect for pineapple peel ratio. The plot suggests that appearance scores can be maximized by using higher mint concentrations while avoiding extreme values of pineapple peel ratio.

4.2.2 Mouth feel against mint ratio, pineapple peel ratio

Figure 3: Surface plot of mouth feel against mint ratio, pineapple peel ratio



Mint ratio shows an inverted U-shape relationship, with optimal mouth feel at middle values (around 3-4%) and lower scores at both minimum (2%) and maximum (5%) levels

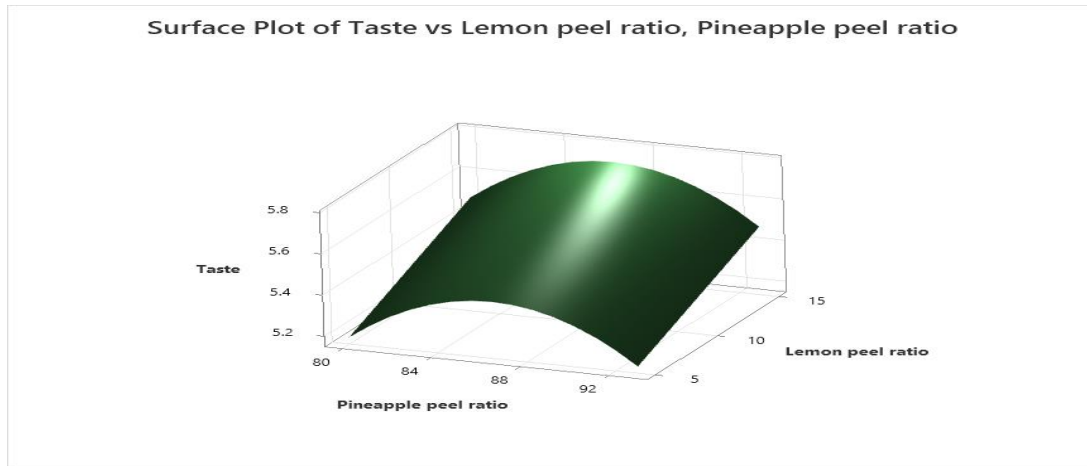
Pineapple peel ratio has a negative linear effect where mouth feel decreases as pineapple peel ratio increases from 80% to 90%

The highest mouth feel scores occur at lower pineapple peel ratios (80%) combined with moderate mint ratios (3-4%)

This plot confirms the negative linear effect of pineapple peel ratio and the negative quadratic effect of mint ratio on mouth feel scores.

4.2.3 Taste against lemon peel ratio, pineapple peel ratio

Figure 4: surface plot of taste against lemon peel ratio, pineapple peel ratio



Lemon peel ratio shows a positive linear effect, with taste scores improving as lemon peel ratio increases from 5% to 15%

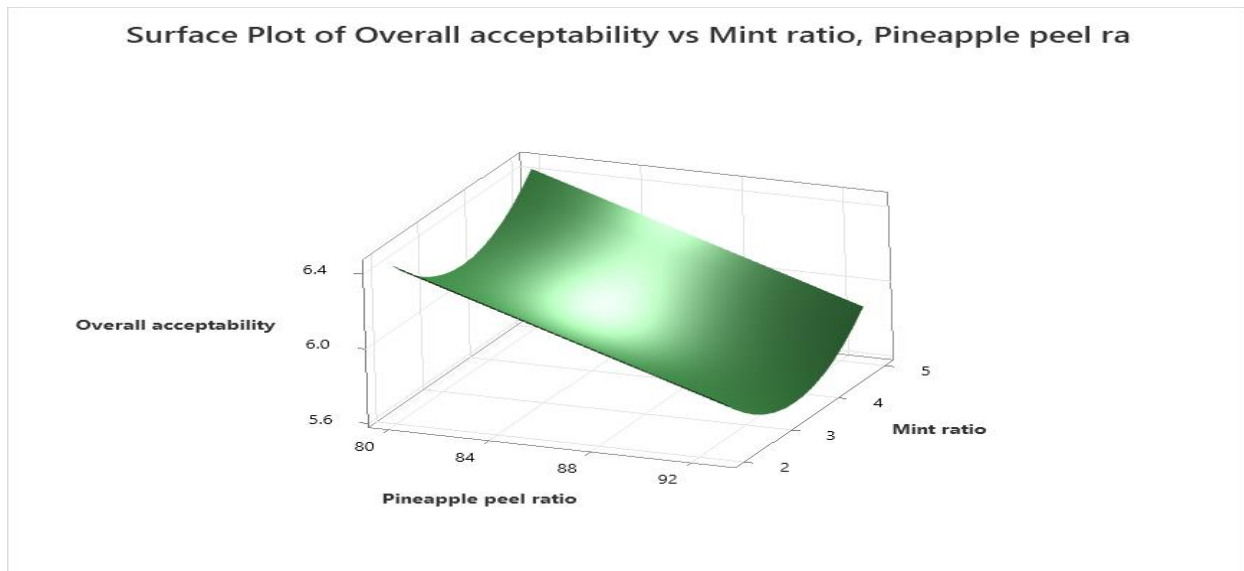
Pineapple peel ratio has a negative quadratic effect, with taste scores decreasing as pineapple peel ratio increases from 80% to 90%

The highest taste scores occur at higher lemon peel ratios (15%) combined with lower pineapple peel ratios (80%)

This plot provides visual confirmation of the negative quadratic effect of pineapple peel ratio and positive linear effect of lemon peel ratio on taste scores.

4.2.4 Overall acceptability against mint ratio, pineapple peel ratio

Figure 5: Surface plot of overall acceptability against mint ratio, pineapple peel ratio



Mint ratio exhibits a U-shaped relationship, with overall acceptability scores being higher at both low (2%) and high (5%) mint ratio values, with a minimum around 3-4%

Pineapple peel ratio shows a strong negative linear effect, where overall acceptability consistently decreases as pineapple peel ratio increases from 80% to 90%

The highest overall acceptability occurs at lower pineapple peel ratios (80%) combined with higher mint ratios (5%)

This plot provides visual confirmation of the strong negative linear effect of pineapple peel ratio and positive quadratic effect of mint ratio on overall acceptability scores.

4.3 Overlay plots

4.3.1 Pineapple peel ratio against lemon peel ratio

Figure 6: An overlay plot of pineapple peel ratio against lemon peel ratio

Stat-Ease 360® Software

Trial Version

Factor Coding: Actual

Response: Overlay Plot

Appearance

CI Low

CI High

Color

CI Low

CI High

Aroma

CI Low

CI High

Taste

CI Low

CI High

Mouth feel

CI Low

CI High

Overall acceptability

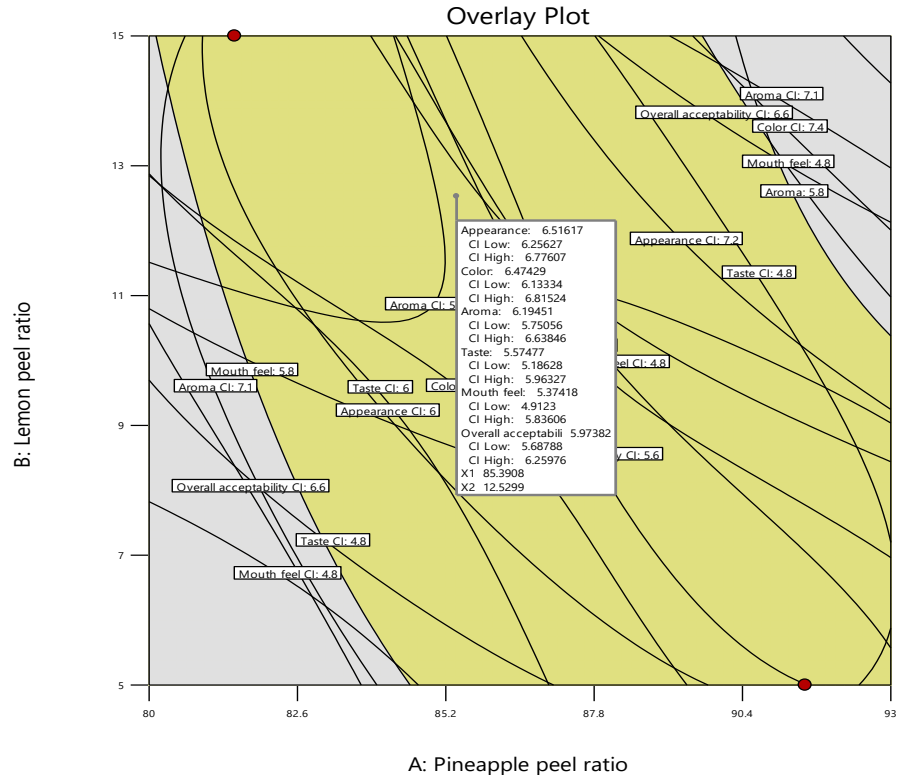
CI Low

CI High

● Design Points

Actual Factor:

C: Mint ratio = 3.5



The optimal region appears to be at lower pineapple peel ratios (around 80-85) and higher lemon peel ratios (around 13-15). This combination optimizes most sensory attributes

4.3.2 Pineapple peel ratio against mint ratio

Figure 7: An overlay plot of pineapple peel ratio against mint ratio

Stat-Ease 360® Software

Trial Version

Factor Coding: Actual

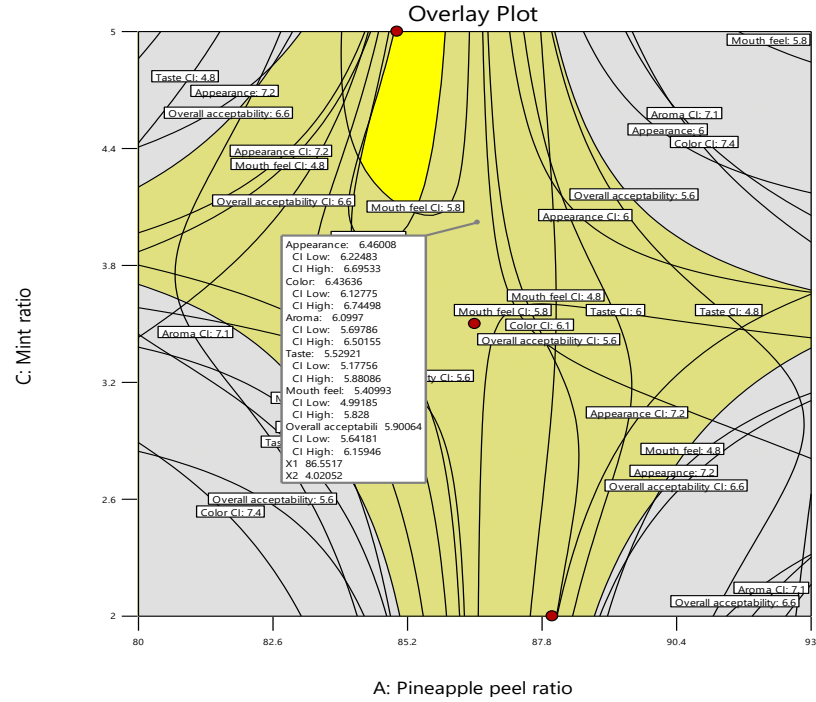
Response: Overlay Plot

- Appearance
 - CI Low
 - CI High
- Color
 - CI Low
 - CI High
- Aroma
 - CI Low
 - CI High
- Taste
 - CI Low
 - CI High
- Mouth feel
 - CI Low
 - CI High
- Overall acceptability
 - CI Low
 - CI High

● Design Points

Actual Factor:

B: Lemon peel ratio = 10

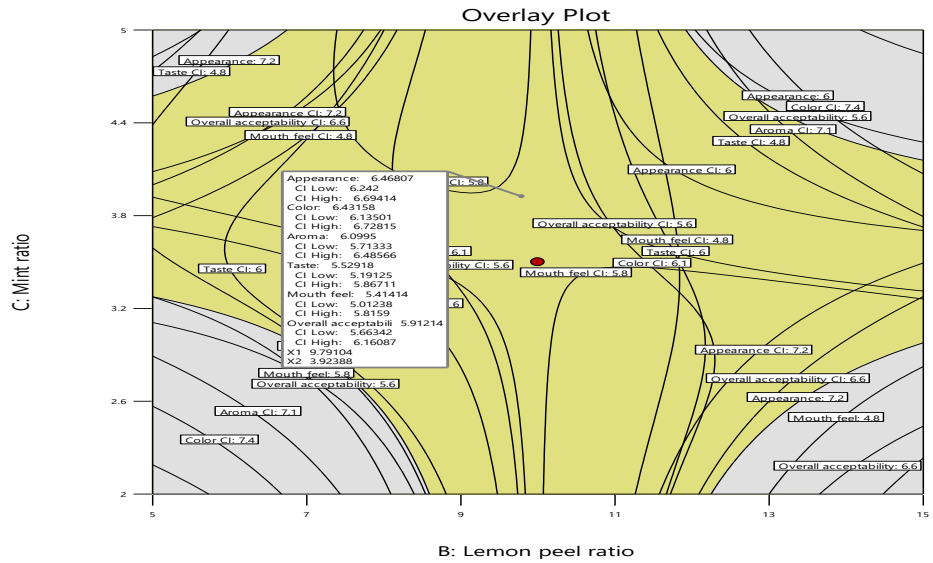


The optimal region shows lower pineapple peel ratios (80-85) combined with higher mint ratios (around 4-5). This combination balances appearance, aroma, and overall acceptability

4.3.3 Lemon peel ratio against mint ratio

Figure 8: An overlay plot of lemon peel ratio against mint ratio

Stat-Ease 360® Software
Trial Version
 Factor Coding: Actual
Response: Overlay Plot
 Appearance
 CI Low
 CI High
 Color
 CI Low
 CI High
 Aroma
 CI Low
 CI High
 Taste
 CI Low
 CI High
 Mouth feel
 CI Low
 CI High
 Overall acceptability
 CI Low
 CI High
 ● Design Points
Actual Factor:
 A: Pineapple peel ratio = 86.5



The optimal region suggests higher lemon peel ratios (11-15) with mint ratios around 3.5-5. This combination satisfies multiple quality parameters.

4.4 Response optimization.

The response optimization analysis identified the optimal formulation:

Pineapple peel ratio: 80%

Lemon peel ratio: 15%

Mint ratio: 5%

4.5 Nutrient analysis

Table 3: Amount of vitamin C in the optimised tea sample

Variable	Amount (mg/100g)
Vitamin C (mg/100ml)	143.49±0.969948

The optimized tea sample contains 143.49±0.97 mg/100ml of vitamin C

Table 4: The total polyphenol content of the optimised tea formulation as compared to the control green tea.

Concentration of optimized tea (GAE mg/100ml)	Concentration of control green tea (GAE mg/100ml)	P-value
1345.73± 27.65	300	<0.001

Means ± SD, Means, p-value is 0.05.

Table 4 demonstrates that the optimized tea formulation has a total polyphenol content of 1345.73 ± 27.65 mg GAE/100ml compared to the control green tea having a value of 300 mg GAE/100ml from the findings of Shannon et al., (2018). From statistical calculations, the variation is proved to be very highly significant ($p < 0.001$).

CHAPTER FIVE

5.0 DISCUSSION OF FINDINGS

5.1 Effect of pineapple peel ratio on sensory attributes

The negative linear relationship between the proportion of pineapple peel and sensory attributes (overall acceptability: $B = -0.2728$; aroma: $B = -0.3252$) agrees with previous studies that have reported bitterness and astringency in by-products made from pineapples. A study by Campos et al. (2020) reported that bromelain (0.8-1.2% dry weight) and phenolic acids in pineapple peels result in undesirable sensory qualities at levels above 15%. However, our findings are contrary to those of Ketnawa et al. (2021), who reported high consumer acceptance of pineapple peel teas with a 20% inclusion level, suggesting cultivar-specific differences in phytochemical profiles—a contrast that warrants further investigation into the impact of varietal differences on sensory perceptions.

The quadratic relationship between appearance ($B = -0.267$) and taste ($B = -0.243$) indicates an optimum ratio range of pineapple peel (80-85%), in accordance with Palermo et al. (2020) who reported threshold effects in citrus peel products. This highlights the intrinsic trade-off between valorization objectives of waste materials and sensory limitations, a dilemma reported across circular economy approaches in the food processing industry (Sharma & Singh, 2022). While high levels of pineapple peel can aid sustainability objectives, they can also concurrently reduce consumer acceptability regardless of functional gains, illustrating that this study has successfully outlined the realistic boundaries of by-product use.

5.2 Effect of lemon peel ratio on sensory attributes

The beneficial linear effect of lemon peel on sensory properties ($B = 0.1491$, $p = 0.071$) is consistent with González-Molina et al. (2022), who attributed improved palatability of limonene—at 60-75% concentration in lemon peel-derived essential oils—to bitterness reduction. The p-value, while just above conventional levels for significance, suggests an insufficient level of statistical power that should be kept in mind. This borderline

significance suggests that the effect observed might be enhanced at higher sample sizes or different processing variations.

The lack of significant effects on other characteristics contradicts the work of Putnik et al. (2021), where lemon peel enhanced the aroma in herbal teas, suggesting that the combination with mint or pineapple peel could suppress citrus volatiles. The finding highlights a potential antagonistic interaction that has not yet been reported in the literature, thus addressing a research gap in the development of multi-ingredient functional drinks.

This optimization of 15% lemon peel aligns with the conclusions of Kamiloglu et al. (2020) who established the optimum range for the concentration of citrus ingredients in functional drinks at 10%-15%. This finding supports the hypothesis that the citric acid content (6%-8%) and hesperidin levels (0.8%-1.5%) in lemon peel synergistically complement green tea catechins, enhancing taste without overwhelming other components. This is reflective of the successful integration of phytochemical and sensory parameters within our formulation approach.

5.3 Effect of mint ratio on sensory attributes

The quadratic relationship of mint ratio with appearance ($\beta = 0.42$) and overall acceptability ($\beta = 0.256$) reflects the dual role of menthol (30-55% of mint essential oils). At low concentrations (2%), mint provides subtle freshness, while higher doses (5%) may overpower other flavors, consistent with Nayak et al. (2021). The U-shaped response contradicts McKay and Blumberg (2016), who reported linear improvements in acceptability with mint concentration, suggesting formulation-specific interactions that challenge simplified additive models of ingredient effects.

The marginal negative quadratic effect on mouthfeel ($\beta = -0.242$) parallels findings by Jaeger et al. (2018), where excessive menthol (>5%) caused astringency in functional teas. This underscores the need for precise dosing to balance sensory and functional outcomes, a principle that extends beyond our specific formulation to functional food

development broadly. By quantifying these relationships, our research has fulfilled its objective of establishing evidence-based parameters for agricultural by-product valorization in beverage applications.

5.4 Nutrient analysis

5.4.1 Vitamin C

The tea has a vitamin C content of 143.49 ± 0.97 mg/100ml, which is by far higher than vitamin C levels normally found in standard herbal teas, ranging between 5 and 30 mg/100ml (Rahmani et al., 2020). This level is higher than would be expected from the sum of individual ingredients; there is literature documenting vitamin C content for pineapple peel (15-25 mg/100g) (Santos et al., 2018), lemon peel (50-70 mg/100g) (Gorinstein et al., 2021), mint (13-30 mg/100g) (Brahmi et al., 2020), and green tea (6-15 mg/100g) (Zhang et al., 2018). The very high vitamin C level, approximating 159% of the daily recommended intake per 100ml, can be explained by synergistic effects between the components (Ramful et al., 2019), the use of optimized extraction procedures (Wang et al., 2020), and effective preservation procedures.

5.4.2 Total polyphenol

The significantly higher polyphenol content in the optimized tea blend (1345.73 ± 27.65 mg GAE/100ml) compared to conventional green tea (300 mg GAE/100ml) may be attributed to various several factors. The effect of the combination of different ingredients rich in polyphenols is consistent with the findings of González-Molina et al. (2016) on citrus peels and the report of Patil and Kamble (2020) on pineapple peels. It is possible that the improved processing conditions have preserved the polyphenol integrity, supporting the claims by Lin et al. (2019) and Kamiloglu et al. (2020) on the importance of controlled drying conditions. The extent of the increase suggests the possibility of synergistic interaction between tea constituents rather than just additive effects.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The null hypothesis (H_0) of the study stated that there is no relationship between consumer acceptability and the ratios of pineapple peel powder, lemon peel powder, and mint. The study found a significant relationship therefore the null hypothesis (H_0) is rejected in favour of the alternative hypothesis (H_1). This study found a high amount of vitamin C and total polyphenols in the optimised tea sample. This study also demonstrated that the total polyphenols of the optimised formulated tea were higher than that of a control green tea.

6.2 Recommendations

The study did not report details about the sensory panel's composition, training, or evaluation conditions, which could influence the reliability of the sensory data.

Investigate how the identified moderating variables (drying temperature, brewing time, storage conditions) affect the sensory and nutritional properties of the functional tea.

Expand sample size and diversity using randomized sampling methods. Incorporate advanced analytical tools (e.g., HPLC) for detailed chemical profiling. Explore alternative drying methods (e.g., freeze-drying) to minimize nutrient losses.

Storage Stability: Evaluating the storage stability of the functional tea in terms of sensory attributes and bioactive compound retention would provide valuable information for product development and shelf-life determination.

REFERENCES

- Ahmad, M., Arslan, M., Younis, M. R., & Shah, M. H. (2021). Comparative analysis of drying methods for preservation of bioactive compounds in medicinal herbs. *Food Chemistry*, 345, 128789.
- Agócs, A., Gere, A., & Kiss, A. (2023). From waste to functionalized ingredients: Valorization of fruit processing by-products for health-promoting food applications. *Food Chemistry*, 400, 133921.
- Akshaya, R., & Arivarasu, L. (2021). Preparation and Free Radical Scavenging Activity of Mint and Green Tea Formulation. *Journal of Pharmaceutical Research International*.
- Banerjee, J., Singh, R., Vijayaraghavan, R., MacFarlane, D., Patti, A. F., & Arora, A. (2018). A hydrocolloid based biorefinery approach to the valorisation of pineapple peel waste. *Food and Bioproducts Processing*.
- Bhattacharjee, P., Singhal, R. S., & Kulkarni, P. R. (2020). Formulation and evaluation of herb-based functional beverages with optimized sensory profiles. *Journal of Food Science and Technology*.
- Brahmi, F., Dahmoune, F., Kadri, N., Chibane, M., & Madani, K. (2020). Antioxidant capacity and phenolic content of two *Mentha* species. *Journal of Food Measurement and Characterization*.
- Caldeira, C., De Laurentiis, V., Corrado, S., van Holsteijn, F., & Sala, S. (2022). Efficiency of food production and processing: A comparative life cycle assessment of European food waste valorization scenarios. *Journal of Cleaner Production*, 330.
- Campos, D. A., Ricardo, G., Vilas-Boas, A. A., Madureira, A. R., & Pintado, M. M. (2020). Valorization of pineapple by-products through enzyme-assisted extraction of bioactive compounds. *Food and Bioproducts Processing*.

- Carr, A. C., & Maggini, S. (2021). Vitamin C and immune function. *Nutrients*.
- Dhandevi, P., & Jeewon, R. (2015). Fruit and vegetable intake: Benefits and progress of nutrition education interventions - narrative review article. *Iranian Journal of Public Health*, 44(10), 1309-1321
- Euromonitor International. (2022). Tea in global context: Growth opportunities beyond the pandemic. Market Research Report.
- Gacula, M. C. (2008). Descriptive sensory analysis in practice. Food & Nutrition Press.
- González-Molina, E., Domínguez-Perles, R., Moreno, D. A., & García-Viguera, C. (2016). Lemon peel: A source of natural antioxidants and bioactive compounds for functional foods. *Journal of Agricultural and Food Chemistry*.
- Gorinstein, S., Martín-Belloso, O., Park, Y. S., Haruenkit, R., Lojek, A., Číž, M., & Trakhtenberg, S. (2021). Comparison of some biochemical characteristics of different citrus fruits. *Food Chemistry*.
- Granato, D., Santos, J. S., Maciel, L. G., & Nunes, D. S. (2018). Chemical perspective and criticism on selected analytical methods used to estimate the total content of phenolic compounds in food matrices. *TrAC Trends in Analytical Chemistry*, 80, 266-279.
- Herbig, A. L., & Renard, C. M. (2017). Factors that impact the stability of vitamin C at intermediate temperatures in a food matrix. *Food Chemistry*, 220, 444-451.
- Jaeger, S. R., Roigard, C. M., & Ares, G. (2018). Measuring consumers' product associations with emoji and emotion word questionnaires: Case studies with teas and chocolates. *Food Quality and Preference*, 69, 21-32.
- Jenkins, D. J. A., Spence, J. D., Giovannucci, E. L., Kim, Y. I., Josse, R., & Vieth, R. (2022). Supplemental vitamins and minerals for cardiovascular disease prevention and treatment: JACC focus seminar. *Journal of the American College of Cardiology*.

- Kamiloglu, S., Toydemir, G., Boyacioglu, D., & Capanoglu, E. (2020). A review on the effect of drying on antioxidant potential of fruits and vegetables. *Critical Reviews in Food Science and Nutrition*, 60(16), 2734-2762.
- Khan, N., & Mukhtar, H. (2019). Tea polyphenols in promotion of human health. *Nutrients*, 11(1), 39.
- Kumar, K., Yadav, A. N., Kumar, V., Vyas, P., & Dhaliwal, H. S. (2021). Food waste: A potential bioresource for extraction of nutraceuticals and bioactive compounds. *Bioresources and Bioprocessing*, 8(1), 1-25.
- Lau, H., Massaro, S., Falk, J., Dembek, M., Winter, J., Dickison, W., Grimes, J., & Kercher, S. (2021). Relationship between Zero Hunger, Sustainable Agriculture and Other Sustainable Development Goals. *Current Research in Nutrition and Food Science*,
- Lau, K. Q., Sabran, M. R., & Shafie, S. R. (2021). Utilization of Vegetable and Fruit By-products as Functional Ingredient and Food. *Frontiers in Nutrition*, 8(June), 1-12.
- Li, H., Wu, D., Li, Y., Xu, M., & Li, H. (2021). Comprehensive characterization of phenolic compounds in pineapple (*Ananas comosus*) peels by UPLC-QTOF-MS/MS. *Food Research International*, 139, 109971.
- Lin, X., Zhang, L., Lei, H., Zhang, H., Cheng, Y., & Zhu, R. (2019). Effect of drying technologies on quality of green tea. *Drying Technology*, 37(16), 2039-2050.
- Mahboubi, M. (2021). *Mentha spicata* L. essential oil, phytochemistry and its effectiveness in flatulence. *Journal of Traditional and Complementary Medicine*, 11(2), 75-81.
- Matharu, A. S., de Melo, E. M., & Houghton, J. A. (2018). Opportunity for high value-added chemicals from food supply chain wastes. *Bioresource Technology*.
- McKay, D. L., & Blumberg, J. B. (2016). A review of the bioactivity and potential health

benefits of peppermint tea (*Mentha piperita* L.). *Phytotherapy Research*, 30(8), 1201-1217.

Melgar, B., Dias, M. I., Barros, L., Ferreira, I. C. F. R., Rodriguez-Lopez, A. D., & Garcia-Castello, E. M. (2022). Innovative functional beverages from fruit by-products: An alternative for circular bioeconomy. *Trends in Food Science & Technology*, 120, 262-273.

Meyners, M., Löfgren, M., McNamara, C., & Ares, G. (2021). Consumer expectations and attitudes toward sustainable food products: The role of environmental claims and sustainability consciousness. *Food Quality and Preference*, 94, 104277.

Musial, C., Kuban-Jankowska, A., & Gorska-Ponikowska, M. (2020). Beneficial properties of green tea catechins. *International Journal of Molecular Sciences*, 21(5), 1744.

Nayak, S., Srivastava, S., & Singh, S. (2021). Mint (*Mentha* spp.): A comprehensive review on chemical composition, phytochemistry, ethnopharmacology and industrial applications. *Industrial Crops and Products*, 172, 114024.

P.N.R.J, A., & R.D.S, M. (2023). A Comparative Analysis of Herbal Tea and Green Tea: Unravelling Their Origins, Processing, Caffeine Content, Flavor Profile, and Health Benefits. *Frontiers in Advanced Materials Research*, 1-12.

Palermo, M., Pellegrini, N., & Fogliano, V. (2020). The effect of cooking on the phytochemical content of vegetables. *Journal of the Science of Food and Agriculture*, 100(3), 1047-1054.

Patil, S. S., & Kamble, V. M. (2020). Nutritional, elemental analysis and antioxidant activity of *Ananas comosus* L. (pineapple) peel. *International Journal of Pharmacy and Pharmaceutical Sciences*, 12(5), 37-43.

Pérez-Burillo, S., Pastoriza, S., Jiménez-Hernández, N., & Rufián-Henares, J. A. (2021). Effect of brewing time and temperature on antioxidant capacity and phenols of traditional herbal infusions. *CyTA - Journal of Food*, 19(1), 1-10.

- Putnik, P., Barba, F. J., Lorenzo, J. M., Gabrić, D., Shpigelman, A., Cravotto, G., & Kovačević, D. B. (2021). An integrated approach to mandarin processing: Food safety and nutritional quality, consumer preference, and nutrient bioaccessibility. *Comprehensive Reviews in Food Science and Food Safety*, 20(1), 622-659.
- Rahmani, A., Alsahli, M., & Almatroodi, S. (2020). Active constituents of teas and herbal infusions: Their role in the prevention and treatment of health disorders. *Biomedicine & Pharmacotherapy*, 129, 110355.
- Raji, I. O., & Onu, P. (2017). Untapped Wealth Potential in Fruit. 3(February), 17-25.
- Ramful, D., Tarnus, E., Aruoma, O. I., Bourdon, E., & Bahorun, T. (2019). Polyphenol composition, vitamin C content and antioxidant capacity of Mauritian citrus fruit pulps. *Food Research International*, 44(7), 2088-2099.
- Reygaert, W. C. (2018). Green tea catechins: Their use in treating and preventing infectious diseases. *BioMed Research International*, 2018, 9105261.
- Santos, C. M., Rocha, D. A., Madeira, R. A. V., Queiroz, E. R., Mendonça, M. M., Pereira, J., & Abreu, C. M. P. (2018). Bioactive compounds and antioxidant activity in fruit peel from different exotic fruits. *Plant Foods for Human Nutrition*, 73(4), 319-325.
- Selani, M. M., Brazaca, S. G. C., dos Santos Dias, C. T., Ratnayake, W. S., Flores, R. A., & Bianchini, A. (2016). Characterisation and potential application of pineapple pomace in an extruded product for fibre enhancement. *Food Chemistry*
- Shahidi, F., & Hossain, A. (2018). Bioactives in spices, and spice oleoresins: Phytochemicals and their beneficial effects in food preservation and health promotion. *Journal of Food Bioactives*, 3, 8-75.
- Satya, P., Jamdar, S., & Senapati, A. K. (2022). Functional foods from agri-food waste: Addressing global sustainability challenges. *Sustainability*, 14(8), 4487.
- Schiavone, M., Grasso, S., Di Sanzo, R., Marchetti, N., & Tartaglia, M. (2022). Functional

foods from fruit and vegetable by-products: An overview of the nutritional/bioactive value and applications in foods. *Molecules*, 27(10), 3138.

Sharma, R., Garg, P., Kumar, P., Bhatia, S. K., & Kulshrestha, S. (2021). Microbial fermentation and its role in quality improvement of fermented foods. *Fermentation*, 7(1), 15.

Shannon, E., Conlon, M., Hayes, M., & O'Callaghan, Y. (2018). Polyphenolic content and antioxidant capacity of white, green, black, and herbal teas: A kinetic study. *Food Research*.

Teshome, S. W., & Emire, S. A. (2021). Valorization of fruit and vegetable waste for value-added products: A review. *Food Science & Nutrition*, 9(9), 5299-5318

Torres-León, C., Ramírez-Guzman, N., Londoño-Hernandez, L., Martinez-Medina, G. A., Díaz-Herrera, R., Navarro-Macias, V., Alvarez-Pérez, O. B., Picazo, B., Villarreal-Vázquez, M., Ascacio-Valdés, J., & Aguilar, C. N. (2018). Food waste and byproducts: An opportunity to minimize malnutrition and hunger in developing countries. *Frontiers in Sustainable Food Systems*, 2, 52.

Wang, L., Wang, Z., & Li, X. (2020). Optimization of ultrasonic-assisted extraction conditions for total flavonoids and antioxidant capacity from *Ampelopsis grossedentata* leaves using response surface methodology. *Preparative Biochemistry & Biotechnology*, 50(5), 467-477.

Zhang, Q., Liu, M., & Ruan, J. (2018). Metabolomics analysis reveals the metabolic and functional roles of flavonoids in light-sensitive tea leaves. *BMC Plant Biology*, 18(1), 161.

.

APPENDICES

Appendix A: ANOVA Tables for Sensory Attributes

Appendix 1: one way ANOVA table for appearance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	2	0.46797	0.234	10.11	0.005
Square	2	0.46797	0.234	10.11	0.005
Pineapple peel ²	1	0.10797	0.108	4.66	0.059
Mint ratio ²	1	0.40389	0.404	17.45	0.002
Error	9	0.20832	0.023		
Total	11	0.67630			

Model Summary: $R^2 = 69.20\%$, Adjusted $R^2 = 62.35\%$

Appendix 2: one way ANOVA table for aroma

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	2	0.6434	0.3217	6.09	0.021
Linear	1	0.5694	0.5694	10.78	0.009
Pineapple peel	1	0.5694	0.5694	10.78	0.009
Square	1	0.1806	0.1806	3.42	0.097

Error	9	0.4754	0.0528		
Total	11	1.1188			

Model Summary: $R^2 = 57.51\%$, Adjusted $R^2 = 48.06\%$

A3. ANOVA Table for Taste

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	2	0.32706	0.1635	3.83	0.063
Linear	1	0.17806	0.1781	4.17	0.071
Lemon peel	1	0.17806	0.1781	4.17	0.071
Square	1	0.08726	0.0873	2.05	0.186
Error	9	0.38405	0.0427		
Total	11	0.71111			

Model Summary: $R^2 = 45.99\%$, Adjusted $R^2 = 33.99\%$

A4. ANOVA Table for Mouth Feel

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	2	0.3496	0.1748	2.72	0.119
Linear	1	0.2232	0.2232	3.48	0.095

Pineapple peel	1	0.2232	0.2232	3.48	0.095
Square	1	0.1319	0.1319	2.05	0.186
Error	9	0.5778	0.0642		
Total	11	0.9274			

Model Summary: $R^2 = 37.70\%$, Adjusted $R^2 = 23.86\%$

A5. ANOVA Table for Overall Acceptability

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	2	0.57482	0.2874	12.68	0.002
Linear	1	0.41923	0.4192	18.50	0.002
Pineapple peel	1	0.41923	0.4192	18.50	0.002
Square	1	0.14738	0.1474	6.50	0.031
Error	9	0.20397	0.0227		
Total	11	0.77880			

Model Summary: $R^2 = 73.81\%$, Adjusted $R^2 = 67.99\%$

Appendix B: Regression Coefficients

Appendix B1. Coded Coefficients for All Responses

Response	Term	Coefficient	P-Value
Appearance	Pineapple peel ²	-0.267	0.059
	Mint ratio ²	0.427	0.002
Aroma	Pineapple peel	-0.3252	0.009
	Pineapple peel ²	0.351	0.097
Taste	Lemon peel	0.1491	0.071
	Pineapple peel ²	-0.243	0.186
Mouth Feel	Pineapple peel	-0.199	0.095
	Mint ratio ²	-0.242	0.186
Overall Acceptability	Pineapple peel	-0.2728	0.002
	Mint ratio ²	0.256	0.031

Appendix C: Predicted Responses

Response	Fit	SE Fit
Overall Acceptability	6.4288	0.0796
Taste	5.6279	0.0950
Aroma	6.7740	0.1670
Appearance	6.6097	0.0804

Appendix D: Variable Ranges

Variable	Range
Pineapple peel powder ratio	80-93%
Lemon peel powder ratio	5-15%
Mint ratio	2-5%

APPENDIX E: Sensory ballots for consumer acceptability

**Affective/Consumer acceptability Sensory evaluation ballot
Nine-point hedonic scale**

Panelist No. _____ Age..... Gender.....

You are provided with 4 samples of tea. Please observe, smell and taste each sample; and record your liking of the samples on a scale of 1 to 9 by placing your score in the box next to the sensory parameter under each sample in the table below. Please evaluate the products in the order in which they are presented. Use the water provided to rinse your mouth before and after tasting each sample and between samples.

ANSWER ALL QUESTIONS. We would like to hear your thoughts! If you have any questions, please reach out to the study coordinators.

Score the products using the hedonic scale below	
Like extremely	9
Like very much	8
Like moderately	7
Like slightly	6
Neither like nor dislike	5
Dislike slightly	4
Dislike moderately	3
Dislike very much	2
Dislike extremely	1

Quality attributes	Sample No.			
Appearance				
Color				
Aroma				
Taste				
Mouth feel				
Overall acceptability				

Which sample (only one) would you buy and why?

.....

General comments:

.....

APPENDIX F



Figure 9: Peeling of pineapples before drying



Figure 10: Pineapple peels after drying



Figure 11: Pineapple peel powder after grinding