KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI, GHANA

DEPARTMENT OF BIOCHEMISTRY AND BIOTECHNOLOGY

COLLEGE OF SCIENCE

FORMULATION AND SENSORY EVALUATION OF HERB TEA FROM *MORINGA OLEIFERA, HIBISCUS SABDARIFFA AND CYMBOPOGON CITRATUS*

A THESIS SUBMITTED TO THE DEPARTMENT OF BIOCHEMISTRY AND BIOTECHNOLOGY, KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF THE DEGREE OF MASTER OF SCIENCE (FOOD SCIENCE AND TECHNOLOGY)

BY

NICHOLAS EKOW ANESI DE-HEER

OCTOBER 2011

DECLARATION

STUDENT:

I hereby declare that this thesis is the outcome of my own original research and that it has neither in part nor in whole been presented for another certificate in this university or elsewhwere.

NAME: Nicholas Ekow Anesi de-Heer **SIGNATURE……**

DATE: …….

SUPERVISORS:

We hereby declare that the preparation and presentation of this project work were supervised in accordance with guidelines on the supervision of project work laid down by the Kwame Nkrumah University of Science and Technology.

NAME: Prof. (Mrs) Ibok Oduro **SIGNATURE……**

DATE: …….

NAME: Dr. Peter Twumasi **SIGNATURE……**

DATE: ……..

DEDICATION

To the hungry in Africa; and all who share the dream of ending hunger in Africa and the world over.

ACKNOWLEDGEMENT

Completing my research and writing this thesis has been, in many ways, like a journey up Mount Everest; long, steep and dotted with many moments of discouragement. The view from the mountaintop leaves me dizzy with nostalgia, and I recount with a profound sense of gratitude, the several personalities on whose support I leaned during my journey.

I am forever grateful to my supervisors, Prof. Mrs. Ibok Oduro and Dr. Peter Twumasi, who provided sound guidance throughout the work. Without their patience and encouragement, this project would not have seen the life of day. I am indebted to Mr. Amaglo Newton, whose passion for Moringa research led him to provide all the Moringa samples and bag all the formulations into teabags free of charge. Also deserving mention is my good friend, Mr. Tohib Sule, who assisted me immensely in the latter stages of my work. I was fortunate to have sat across the office desks of many lecturers who provided pieces of advice and information. From KNUST I thank Mr. Ter Larbi, Mr. Agorku Eric Selorm, Mrs Gloria Koomson and Mr Ofosu. I am also grateful to Dr. Esther Sakyi-Dawson, Mr. David Nana Adjei and Mr. Felix Worlanyo of the University of Ghana.

I thank my family who have been a rock of support for me every stage of my life; Nana Esi my cousin, the Ekems, Ewuresi my dear sister, and my heroic mother, Mrs. Joyce de-Heer. To Mrs. Angela de-Heer, my best friend and partner, who cheered me on every step of this marathon, I cannot express my heartfelt appreciation enough. Finally, to Him who gives me life, for whom and by whom I have my being; He who will help me ascend higher heights; Glory be Unto His Name. It is the Lord who has done it and it is marvelous in our eyes.

ABSTRACT

The sensory appeal of tea, like all food products, is an important consideration in new product development. Tea in general and herb tea in particular, are gaining increasing consumer attention due to a growing awareness of health benefits derived from their consumption. Even though several underutilized plants exist with potential for processing into herb tea, research in product development of herb teas is limited. The objectives of the study were (1) to conduct chemical analyses on three herbs – *Cymbopogon citratus* leaves, *Hibiscus sabdariffa* calyces and *Moringa oleifera* leaves – in order to assess their potential for food product development; (2) to conduct acceptance tests on herb tea prepared from formulations of the herbs; and (3) to generate descriptive vocabulary on the sensory properties of herb tea. The herbs were unblanched and solar-dried. Standard methods were used to measure proximate parameters, water soluble extractives (WSE), light petroleum extractives (LPE), pH, total polyphenolics content (TPC) and minerals (Ca, Fe, Cu and Zn). Fifty (50) untrained panelists conducted acceptance tests on infusions from nine formulations and one control, and a nine-member trained panel conducted descriptive tests on infusions from three selected blends. Results of chemical analysis revealed that Moringa, Roselle and Lemon grass had, respectively, TPC of 35.70 mg/g, 27.81 mg/g and 15.37 mg/g; WSE of 7.44%, 12.38% and 4.07%; LPE of 3.48%, 2.71% and 4.1%; pH of 5.47, 2.73 and 4.53. Mineral analyses revealed that Moringa, Roselle and Lemon grass had, respectively, Ca of 412.5 mg/100g, 294 mg/100g and Fe of 12.93 mg/100g; 24.26 mg/100g and 11.58 mg/100g. A total of seventeen (17) descriptors were generated, defined and referenced for herb tea comprising six (6) appearance, three (3) aroma, one (1) flavour, five (5) taste and two (2) mouthfeel descriptors. Herb tea brewed from product 532 (50% Moringa, 30% Roselle and 20% Lemon grass) was the most preferred in colour, flavour, astringency and overall sensory

properties while the control (100% Moringa) brewed the least preferred herb tea in most of the sensory attributes. Product 532 was predominantly reddish in colour (12.56) while the control was yellowish (11.93). Product 532 had high mean scores for Turbidity (12.67), Herbal aroma (11.41), Citrus aroma (11.30), Sour taste (12.15) and Astringency (11.41) while the control had significantly low scores for most of these attributes (≤ 2.33). Herb tea from blend of Moringa, Roselle and Lemon grass was more appealing than herb tea from only Moringa.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

CHAPTER ONE

1.0 INTRODUCTION

The drinking of tea begun in China centuries ago, and has over the years become an inseparable part of most cultures worldwide. Tea is currently the most widely consumed beverage in the world (Schmidt *et al.*, 2005) and therefore ranks as an important world food product. About one tenth of the world production volume of tea is supplied by Kenya which is Africa's largest producer of tea (International Tea Committee, 1998).

Tea is generally consumed for its attractive aroma and taste as well as the unique place it holds in the culture of many societies. In recent times, there is renewed interest in tea because of growing consumer awareness of health benefits derived from tea consumption (McKay and Blumberg, 2002). Tea therefore belongs to a rapidly expanding market of 'wellness beverages' (Byun and Han, 2004).

By definition, tea is an infusion of the leaves or other parts of the evergreen tea plant (*Camellia sp*). Teas have been traditionally categorized into green, oolong and black teas according to the processing conditions employed during manufacturing (Kirk and Sawyer (1997). In recent times, however, a fourth category, called herb teas, is gaining increasing popularity among consumers. Unlike traditional teas, herb teas are prepared from plants other than *Camellia* (Bender, 2003)

Tea preparation follows a simple procedure. Hot water (70 °C to 100 °C) is poured over the plant part(s) in a container and allowed to steep for a few minutes (usually 1 – 5 min) after which the plant material, usually contained in a bag, is removed from the container. The

temperature of the water used and the duration of steeping affect the 'strength' of the tea. Tea is drunk hot, warm or iced. In some cases milk and/or a sweetener such as honey or sucrose may be added before drinking (Hakim *et al.*, 2000).

According to Abbey and Timpo (1990), indigenous herbs are in general heavily under-exploited in spite of their huge dietary potential. It is therefore imperative to explore the potential of indigenous plant materials in the development of new herb teas. Three examples of indigenous plants discussed in this thesis are *Moringa oleifera* (Moringa), *Hibiscus sabdariffa* (Roselle) and *Cymbopogon citratus* (Lemon grass).

Moringa is an easily propagated plant which thrives well in harsh environmental conditions. It is increasingly gaining global attention due to an excellent profile of nutrients and antioxidants. Moringa leaf is rich in minerals, amino acids, vitamins and β-carotene. It also contains a rare combination of health-promoting antioxidants: zeatin, quercetin, sitosterol, caffeoylquinic acid and kaempferol (Anwar *et al*., 2007). Currently, there is growing interest in the use of Moringa leaf as an ingredient in the preparation of herb tea. According to unpublished reports, however, herb tea made solely from Moringa is poor in sensory appeal (Source: personal communication). This may probably be due to the absence of distinctive flavour properties. It may therefore be necessary to combine Moringa with other herbs in developing herb teas as a way of improving its sensory appeal. This is crucial because consumers are generally unwilling to buy food with poor sensory appeal, irrespective of health or nutritional benefits (de Cock *et al.*, 2005).

Roselle is an aromatic, astringent herb with multiple food uses including the preparation of beverages. Roselle is known to impart a characteristic reddish colour and sour taste which many consider appealing in beverages (Blench, 1997).

Lemon grass has been a preferred component of many cuisines for centuries because of its excellent aromatic properties. Infusion of lemon grass leaf gives an aromatic drink with a characteristic lemon flavour (Figueirinha *et al.*, 2008).

1.1 MAIN OBJECTIVE

The main objective of the study is to explore alternative uses for *Moringa oleifera*, *Hibiscus sabdariffa* and *Cymbopogon citratus* by blending the three herbs to produce a herb tea with acceptable sensory properties.

1.2 SPECIFIC OBJECTIVES

The specific objectives of the study are:

- to determine chemical composition of dried *Moringa oleifera* leaves, *Hibiscus sabdariffa* calyces and *Cymbopogon citratus* leaves;
- to perform acceptance tests on infusions prepared from blends of the three herbs; and
- to generate descriptive vocabulary that would characterize the sensory properties of herb tea.

1.3 RESEARCH JUSTIFICATION

Developing new herb tea products from indigenous plants will provide novel uses for underutilized plants. It will further provide consumers with new alternatives to traditional teas. Moreover the research will bring to light the potential of the underutilized plants for food product development. The research will broaden understanding of the sensory characteristics and preferences of herb teas in particular and beverages in general. It will further advance research in herb tea product development.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 TEA – DEFINITION AND TYPES

Tea is, by definition, a beverage prepared by infusion of young leaves, leaf buds and internodes of varieties of the tea plant *Camellia sinensis* or *Camellia assamica* (Bender, 2003).

During the processing of tea, the plant materials usually undergo some level of fermentation. The type of processing conditions, mainly the extent of fermentation, determines the type of tea produced as well as its distinctive characteristics. Kirk and Sawyer (1997) recognized three main types of tea: green tea, oolong tea and black tea.

Processing of green tea involves little or no fermentation and the tea leaf often remains reasonably green. Oolong tea undergoes partial fermentation while black tea undergoes complete fermentation (Taylor and McDowell, 1993; Rinzler, 2001).

Green teas are characterized by inactivation of the enzyme polyphenol oxidase immediately after plucking of the tea shoots. This enzyme is responsible for oxidizing the catechins to theaflavins and thearubigins, the tea pigments responsible for the colour and taste of black teas. The inactivation can be achieved by parching, roasting or steaming the tea shoots. Traditionally, the Chinese roast the tea shoots in a metal roaster and process the tea shoots by using a unidirectional rotatory roller. This type of rolling gives a twist to the leaf and compacts the particles. Chinese green tea is characterized by a roast odour. On the other hand, the Japanese inactivate the tea shoots by steaming, followed by bi-directional rolling.

This rolling makes the shoot surface flat with leaf juice spread over the entire surface (Sharma *et al.,* 2005).

In recent times infusions of dry plant parts of other higher plant species have been given the same generic name 'tea' (Owusu and Odamtten, 1999). Reports from India indicate alternative sources of tea from the leaves of five mangrove species namely *Bruguiera cylindrical* (L) Bl., *Ceriops decandra* (Griff). Ding Hou, *Rhizopora apiculata* Blame, *R., lamarckii* Montr and *R. mucuonata* Lam (Kathiresan, 1965). Previous workers in Europe have formulated tea from leaves of several plants including *Fragaria vesca, Sorbus aucuparia, Filipendula ulmaria, Epilobium anguistifolium* and *Rubus idaeus* (Julkenen-Tito *et al.,* 1988) with abundant aromatic constituents showing therapeutic effects in man. A more appropriate term for these infusions of other plants is 'herb tea'. A herb tea is defined as an 'infusion of leaves, fruits, stems, roots, etc. made from plant parts other than *Camellia sp.*' (Bender, 2003). Other names for herb tea are 'herbal tea' or 'tisane'. In Ghana, the use of Cinnamon (*Cinnamomum zeylanicum* Blume) leaves, Citronella (*Cymbopogon nardus*) leaves, Roselle (*Hibiscus sabdariffa*) calices and other indigenous herbs in making herb tea has become a common practice (Owusu and Odamtten, 1999).

However, within each category of tea, differences in characteristics exist due to factors such as differences in the processing methods used, differences in the stage of maturity of tea leaves at harvest, differences in the type of tree species, and differences in the region where the tea was cultivated (Jung, 2004). Further, some commercial teas may contain additional herbs from other plant materials; pieces of fruit, flowers, etc; intended to impart flavor, color or taste to the tea. Examples include "Earl Grey Tea"; black tea with added bergamot; and Jasmine tea; black tea with added jasmine flowers (Jung, 2004).

All teas – green, oolong, black or herb – are hot water infusions of plant parts enjoyed by many people around the world for their desirable sensory properties, probable health benefits or cultural significance.

2.2 HEALTH BENEFITS OF CONSUMING TEA

Teas were originally consumed for their taste and aroma. However, a recent awareness of their health benefits has increased consumers' interest in the beverage (Khokhar and Magnusdottir 2002; Byun and Han 2004). Specific health claims in various countries include promotion of respiratory health and reduction in cholesterol and blood pressure (MINTEL., 2005). For these reasons, teas are regarded as functional foods along with beverages such as sports drinks, fruit and vegetable juices (Byun and Han 2004).

A functional food is, by definition, food that has a relevant effect on well-being and health, or results in a reduction in disease risk. The functional component of a functional food may be an essential macronutrient or micronutrient, a nutrient that is not considered essential, or a non-nutritive component (Roberfroid, 1999). Even though teas have little nutritional value per se (Hamiltion-Miller, 1995), they are rich in phenolic compounds which have proven health benefits (Marongiu *et al*., 2004). Larson (1988) reported on several biological activities of polyphenols including antibacterial, anti-carcinogenic, anti-inflammatory, anti-viral, anti-allergic, estrogenic, and immune-stimulating effects. They are also known to exhibit high solubility in water (Haslam, 1998).

The global functional food market reached a value of $ 31.7 billion in 1999 with an expected growth of 10% until 2004 (Euromonitor, 2000). Consumers are generally unwilling to buy

food with poor sensory appeal, irrespective of health or nutritional benefits (de Cock *et al.*, 2005). For this reason, a closer attention needs to be given to the sensory properties of functional foods in new product development.

2.3 SENSORY ATTRIBUTES OF TEA

The flavor of tea, particularly green tea, has been studied using both chemical and sensory methods (Chambers and Lee, 2007). Volatile fractions of various teas contain more than 50 aroma active compounds, including ones that could yield nutty, popcorn-like, metallic, floral, meaty, fruity, potato, green, cucumber-like and hay-like characteristics (Kumazawa and Masuda, 2002). Wang *et al.* (2000) found that epigallocatechin gallate and epigallocatechin appeared to play the key role in the changes of sensory qualities of a processed green tea beverage. Age and the extent of fermentation have significant effects on volatile flavor compounds. Teas with the youngest leaves generally have the highest amounts of catechins and amino acids, which could result in off-flavors (Kinugasa *et al.*, 1997).

Ellis (2002) used a variety of terms to describe tea flavor. These included sweet, fragrant, malty, strong, full-bodied, spicy, fragrantly fruity, fresh, herbaceous, smoothly fragrant, deep, astringent, grassytasting, smoky, savory strength, bitter and refreshing. However, no precise definitions or references were provided (Chambers and Lee, 2007).

Other publications (Yamanishi, 1977; Park *et al.*, 1999) have also provided some sensory terminologies. Those authors included terms related to appearance (e.g., color of dried green tea leaves, shape of tea leaves and color of infused green tea); flavor (fresh floral, sweet floral, citrus, sweet fruity, fresh green, sweet, resinous, roasted, dimethyl sulfide-like, green,

burned, acidic, fermented, oily, earthly, moldy, seaweed, dried leaf, nutty, juice of motherwort, acrid); fundamental tastes (bitter, sweet, aftertaste, umami); and mouthfeel properties (astringent, biting/pungent).

A total of sixteen (16) sensory terms developed by Yamanishi (1977) were used by Togari *et al.* (1995) to evaluate and differentiate among green, oolong and black tea, but did not provide references to help with understanding of the attributes. Neither did his work include herb teas. Cho *et al.* (2005) used descriptive analysis to compare 10 canned tea products using 17 different attributes, including floral, lemon, roasted tea, roasted rice tea (artificial), sweet odor, green tea, oolong tea, black tea, boiled milk, arrowroot/rooty, sour taste, sweet taste, chestnut shell, oily, burnt leaf, bitter taste and astringency. Perhaps because the products tested were processed in cans, the list included somewhat generic names of tea such as green tea, oolong tea and black tea to describe tea products. Character references were used, but intensities of the references were not given. All of the studies were conducted on a limited number of samples that may not represent a broad range of teas (Chambers and Lee, 2007).

Sensory attributes of herb teas have received relatively little research attention despite the growing popularity of herb teas worldwide. A wide variety of plant materials with distinctive sensory qualities exist as potential ingredients of herb tea. There is the need for research to explore options for blending different herbs in varying proportions to produce different products. Blends could elicit distinct attributes which may be more desirable in sensory appeal than individual herbs. Further, research must develop descriptive vocabulary to enhance understanding of the sensory qualities of herb tea.

2.4 PREPARATION OF TEA

The extraction procedure during tea preparation is considered one of the most critical factors for determining the sensory characteristics of the beverage (Hara *et al.,* 1995). The extraction of tea is determined by various factors, such as the tea-to-water ratio, length of infusion (Choi *et al.*, 2000), temperature of infusion (Jaganyi and Price 1999; Choi *et al.,* 2000; Jaganyi and Mdletshe 2000; Sharma *et al.,* 2005; Weerts *et al.,* 2005; Xia *et al.,* 2006), type of infusing water (Yau and Haung 2000) and type of tea (Shin 1994; Kim *et al.,* 2002; Liang *et al.,* 2003).

2.5 WORLD PRODUCTION OF TEA

Tea is the most widely consumed beverage in the world, next only to water (Schmidt *et al.,* 2005). The global market for tea is expected to grow from $6.8 billion to $10 billion by end of 2010 (Sloan, 2005).

The average annual global tea production from 1995 to 1997 was approximately 2.6 million tonnes, with a global record of 2.86 million tonnes in 1998 (Table 2.1). World tea production increased at an annual growth rate of 2.8 percent between 1970 and 2000, expanding from 1.27 million tonnes to 2.97 million tonnes. Tea is grown in at least 30 countries on five continents. In the past two decades the most significant change in tea production has been the development of tea plantations in Africa and South America (International Tea Committee, 1998).

The world production of tea is expected to increase further, since the areas under tea production in countries like India, Bangladesh, Kenya, Malawi and Tanzania have been recently expanded (International Tea Committee, 1998).

Tea production is highly centralized. In 1993, five countries – India, China, Sri Lanka, Indonesia and Kenya – accounted for 75% of the world production. Most countries produce tea mainly for export, but in India, China, Japan and Turkey about 70% of the tea produced is consumed within the country. Tea is grown on about 2.5 million hectares of land in Asia (89 percent of global tea cultivated areas) and Africa (8 percent) (International Tea Committee, 1998).

Tea-producing countries can be further divided into two types based on investment – traditional producers of tea, anxious to protect their market shares, who invest particularly in the rehabilitation of trade areas, e.g. India and Sri Lanka; and relatively new producers in the expansionary phase who invest in order to obtain a greater market share e.g. Kenya, Malawi, Tanzania and Uganda (Kirk and Sawyer, 1997).

Table 2.1 1998 World Production of Tea

Country	**Production (tonnes)**	**Percentage of World Production (%)**
India	870, 000	30
China	625, 000	22
Kenya	294, 000	10
Sri-Lanka	281, 000	10
Indonesia	166, 000	6
Turkey	115, 000	4
Japan	83, 000	3
Iran	60, 000	2
Argentina	50, 000	2
Australia	2, 000	0.1
Others	310, 000	11
Total	2, 856, 000	100

Source: International Tea Committee (1998)

2.6 MORINGA (*Moringa oleifera* Lam)

Moringa (*Moringa oleifera* Lam) is one of the best known and most widely distributed and naturalized species of a monogeneric family Moringaceae (Nadkarni 1976; Ramachandran *et al.* 1980) (Figure 2.1). Fully grown, Moringa trees range from 5m to 10m in height (Morton, 1991). The plant is a native of India. It is commonly known in English by names such as Horseradish tree (describing the taste of its roots) and Drumstick tree (describing the shape of its pods) (Ramachandran *et al.*, 1980). In Ghana, it is found wild or cultivated next to kitchens and in gardens (Newton, 2007).

Figure 2.1 Picture of *Moringa oleifera*

2.6.1 GENERAL USES OF MORINGA

Moringa is a multi-purpose tree with virtually every part of the plant being useful. It is known to be extremely valuable in local communities where people have a direct dependence on plants (Booth and Wickens, 1988). The immature pods are often cooked and eaten like green beans. The roots are a popular food in East Africa. The bark of the tree is known to contain a gum that is used as seasoning. The leaves are eaten as vegetable in many cultures, either fresh or as canned. In Ghana, they are cooked and eaten like 'Kontomire' or used to make soups, sauces or salads (Newton, 2007).

Moringa seed oil is suitable for cooking, particularly in salads. It is industrially used for soap manufacturing. Moringa seeds are reported to be among the best natural coagulants ever discovered (Ndabigengesere and Narasiah, 1998). Crushed seeds are a viable replacement for synthetic coagulants (Kalogo *et al.*, 2000). The seeds can also be used as an antiseptic in the treatment of drinking water (Obioma and Adikwu, 1997).

Booth and Wickens (1988) reported several agronomic and industrial uses of *Moringa.* These included alley cropping systems (for biomass production), animal forage (from leaves and treated seed cake), biogas (from leaves), domestic cleaning agents (from crushed leaves), dye (from the wood), fencing material, fertilizer (green manure from leaves), foliar nutrient, gum (from tree trunks), honey clarifier, medicine, ornamental, crop disease prevention, industrial manufacture of newsprint and writing paper, rope-making, tanning hides and water purification. Many indigenous leafy vegetables in Ghana including *Moringa oleifera* are under-exploited with some of them being endangered despite their immense potential value (Abbey and Timpo, 1999). Developing food products from these under-exploited plants will encourage local production of these plants and prevent their extinction.

2.6.2 CHEMICAL COMPOSITION OF MORINGA LEAF

Moringa leaf has been advocated as an outstanding indigenous source of highly digestible proteins with an excellent amino acid profile. It contains the sulphur-containing amino acids methionine and cystine. It is particularly rich in the minerals calcium and iron and the vitamins A, B, C and E (Table 2.2). The leaves are also rich in β-carotene and are an exceptionally good source of fiber (Nambiar *et al.*, 2003).

TABLE 2.2 Vitamin, mineral and amino acid content of Moringa leaf powder

Vitamin	Content (mg/100g)	Mineral	Content (100mg/g)	Amino acid	Content (mg/100g)
A	18.9	Calcium	2003	Arginine	1325
B_1	2.64	Copper	0.57	Histidine	613
B_2	20.5	Iron	28.2	Isoleucine	825
B_3	8.2	Potassium	1324	Leucine	1950
E	11.3	Magnesium	368	Lysine	1325
		Phosphorus	204	Methionine	350
		Sulphur	870	Phenylalanine	1388
		Selenium	0.09	Threonine	1188
		Zinc	3.29	Tryptophan	425
				Valine	1063

Source: Booth and Wickens (1988)

The leaf is also reported to have a wide range of beneficial polyphenolic compounds. These include zeatin, quercetin, β-sitosterol, caffeolquinic acid, rutin, lutein, catechins, isothiocynates and kaempferol (Nambiar and Daniel, 2005).

2.6.3 HEALTH BENEFITS OF CONSUMING MORINGA LEAF

Moringa has been well known for its high medicinal properties in many cultures around the world for many generations. Leaves and other plant parts are extensively used for treating various ailments (The Wealth of India, 1962).

Moringa leaf is known to be beneficial for people with cardiovascular disorders. Moringa leaf juice is also known to have a stabilizing effect on blood pressure (The Wealth of India, 1962). The leaves have been reported to have hypocholesterolaemic (Ghasi *et al*., 2000) and antitumour activities (Murakami *et al*., 1998; Makonnen *et al*., 1997), as well as being helpful

in the treatment of cardiovascular diseases and inflammation (Ezeamuzle *et al*., 1996). Moringa leaves are also known to be useful for people with high risk factors of hypertension (Faizi *et al*., 1998). An infusion of leaf juice has been shown to reduce glucose levels in rabbits (Makonnen *et al.*, 1997) and is known to be helpful for people with diabetes mellitus (Kar *et al*., 2003).

Aqueous leaf extracts regulate thyroid hormone and can be used to treat hyperthyroidism while exhibiting an antioxidant effect (Pal *et al.*, 1995). Leaf extracts also exhibit antispasmodic activity making it useful in diarrhea (Gilani *et al.*, 1992) and gastrointestinal motility disorder (Gilani *et al.*, 1994). Aqueous leaf extracts show antiulcer effect (Pal *et al.*, 1995). Fresh leaf juice was found to inhibit the growth of microorganisms (*Pseudomonas aeruginosa* and *Staphylococcus aureus*), pathogenic to man (Caceres *et al.*, 1991). The leaves have been reported to have anthelmintic activity (Bhattacharya *et al.*, 1982).

2.7 ROSELLE (*Hibiscus sabdariffa* L.)

Roselle (*Hibiscus sabdariffa* L.) is an erect annual herb belonging to the family Malvaceae (Figure 2.2). It originated from Malaysia and is cultivated mainly in tropical and subtropical regions of the world (Appel, 2003). It is known by many names: 'Florida roselle', Florida cranberry' and Indian roselle in the USA; 'asam susur', 'asama paya' and 'asam kumbang' in Malaysia; 'sorrel' or 'Jamaican sorrel' in the Caribbean; 'karkade' or 'carcade' in Sudan; and 'Bisap' in Senegal and Ghana (Morton 1974; Stephens 1994; Tee *et al*., 2002; Wong *et al.*, 2002).

Figure 2.2 Picture of *Hibiscus sabdariffa*

2.7.1 GENERAL USES OF ROSELLE

The calyces of Roselle are used in tropical Africa, West Indies, the Phillipines and Indonesia to make refreshing drinks, tea, syrups, puddings, sauces, condiments and perfume (Esselen and Sammy 1973; Clydesdale *et al.*, 1979; D'Heureux-Calix and Badrie 2004). Roselle extracts are used as raw material of soft drink and medicinal herb preparations (Chen, 2003). Blench (1997) reported that the fleshy, cup-shaped calyces of Roselle are dried and commonly used as tea, drunk hot or cold, after adding some sugar. This beverage, known for its aromatic, astringent and cooling properties, is popular around the world especially in the Caribbean, but also in North-Eastern Africa where the calyces were traditionally chewed to alleviate thirst during long dessert trips. The fleshy Roselle is increasingly gaining popularity in the Americas, where the calyces are used for making jelly, jams and beverages as well as food colorants and chemical dyes. Fresh succulent calyces can also be used to make a kind of chutney, together with ginger, pimento and other spices (Blench, 1997).

Roselle is an important fibre crop and leafy vegetable. In the savannah areas of The Ivory Coast, Ghana and Burkina Fasso, it is widely cultivated for its leaves which are used to prepare a wide variety of cuisines. In Asia, roselle fibre provides a good substitute for jute while the pulp is used in the manufacture of newsprint. In Chad, one of the reasons for

growing the crop is oil. Roselle oil is mainly used for cooking purposes, but can also be used as an ingredient for making paints. Roselle leaves are a source of mucilage used in pharmaceuticals and cosmetics. Of recent interest is the ornamental value of the plant. Farmers in Israel are promoting it as a cut flower. Other countries are using its shrubbery for decorative purposes (Blench, 1997).

2.7.2 CHEMICAL COMPOSITION OF ROSELLE CALYX

Roselle contains a wide range of vitamins and minerals including Vitamin C, calcium, niacin, riboflavin and flavonoids (SRC, 2002). Subramanian and Nair (1972) reported the presence of two main flavonoids in Roselle calyx – gossypetin and hibiscetin – along with their glycosides. Takeda and Yasui (1985) reported the presence of a third flavonoid, quercetin. Roselle calyx has also been demonstrated to be a rich source of anthocyanins (Du and Francis, 1973) and organic acids (Kerharo, 1971).

Chen *et al*. (1998) studied the composition of the volatile constituents of Roselle tea. More than 37 compounds were characterized, which were classified into four groups: fatty acid derivatives, sugar derivatives, phenolic derivatives and terpenoids.

Roselle calyces contain brilliantly red, water-soluble, flavonoid pigments known as anthocyanins (Du and Francis 1973; Mazza and Miniati 2000). Calyx anthocyanin content ranges from 1.7% to 2.75% per dry weight according to Khafaga and Koch (1980). Roselle is therefore an important source of pigments used as food colouring agents (Esselen and Sammy, 1973). Hot water extraction was found to be the most effective method of calyx anthocyanin extraction (Wong *et al*., 2003).

Roselle anthocyanins may exert an effect on consumer perception due to its bright red colour. This is because appearance of food, particularly colour, can have a halo effect which modifies subsequent flavor perception and food acceptability (Nazlin, 1999). Colour is often taken as an index of palatability and nutritional value (Haisman and Clarke, 1975).

Citric and malic acids have been reported as the major organic acids in aqueous extracts of the calyces (Buogo and Picchinenna, 1937; Indovina and Capotummino, 1938; Reaubourg and Monceaux, 1940). Trace amounts of tartaric acid has also been reported (Indovina and Capotummino, 1938). Lin (1975) and Tseng *et al*. (1996) reported the presence of oxalic acids and protocatechuic acids respectively. The calyces are also known to contain significant amounts of ascorbic acid (vitamin C) (Buogo and Picchinenna 1937; Reaubourg and Monceaux 1940). Research by Wong *et al*. (2002) showed that roselle calyx contained 1.4109 mg/g of ascorbic acid. Acids generally play a significant role in influencing the taste of both natural and processed food products by imparting a sour or sharp taste to food. Citric acid, for example, is responsible for the sour taste of lemons, limes, grapefruits, and oranges while acetic acid is responsible for the sour taste of vinegar (Bender, 2003).

Ascorbic acid (Vitamin C) plays a key nutritional role in foods. It is an essential nutrient for humans, a deficiency of which causes scurvy. It is also a potent antioxidant, protecting the body from oxidative stress (Bender, 2003)

2.7.3 HEALTH BENEFITS OF CONSUMING ROSELLE CALYX

Wang *et al*. (2000) suggested that daily consumption of *Hibiscus* anthocyanins might be effective in lowering oxidative damage in living systems. Mazza (2000) detailed the health

effects of anthocyanins as anti-inflammatory, antihepatoxic, antibacterial, antiviral, antallergenic, antithrombic and antioxidant. The anthocyanins of roselle have been used effectively in folk medicines against hypertension, pyrexia and liver disorders (Delgado-Vargas and Paredes-López, 2003).

Aqueous extracts of roselle calyces have been demonstrated to have strong antioxidant effects (Tsai *et al.*, 2002; Hirunpanich *et al.*, 2005). Anthocyanins have been correlated with their antioxidant property in the role of reduction of coronary heart disease and cancer and to enhance the body's immune system (Bridle and Timberlake 1997; Delgado-Vargas *et al.*, 2000; SRC 2002; Tee *et al.*, 2002).

2.8 LEMON GRASS (*Cymbopogon citratus* Stapf)

Lemon grass (*Cymbopogon citratus* Stapf) is a perennial tufted grass, about 60 – 90 cm tall (Figure 2.3). It belongs to the family Graminae and is widely distributed in tropical and sub-tropical regions of the world. It originates from India and is known by other names such as Citronella Grass or Fever Grass (Chisowa *et al.*, 1998).

Figure 2.3 Picture of Cymbopogon citrates

2.8.1 GENERAL USES OF LEMONGRASS

Lemon grass is used in the preparation of a wide variety of dishes. It is a common ingredient in Asian cuisines, particularly teas, curries and soups. Infusion of the leaves gives an aromatic drink used in traditional cuisine for its lemon flavour (Figueirinha *et al.,* 2008).

In some cultures, the leaves are traditionally used as a chewing stick to provide a pleasant fragrance in the mouth. Industrially, lemon grass is used in aromatherapy and manufacture of mosquito repellents, soaps, cosmetics and perfumes. *C. citratus* leaf constitutes a source of essential oil for the flavour and fragrance industries and most uses and phytochemical studies are centred on its volatile compounds (Kasali *et al.*, 2001).

2.8.2 CHEMICAL COMPOSITION OF LEMON GRASS LEAF

Lemon grass leaf is rich in aromatic essential oils. Because *C. citratus* leaves constitute a source of essential oil for the flavour and fragrance industries, most uses and phytochemical studies are centred on their volatile compounds (Baratta *et al.,* 1998; Kasali *et al.,* 2001).

Chisowa *et al.* (1998) isolated 16 compounds in a research to determine the volatile constituents of the essential oils of *Cymbopogon citratus*. The major components were citral (68.4%) and myrcene (18.0%). The citral is composed of two essential oils, geranial (39.0%) and neral (29.4%). Other components of the oil identified in minute quantities were limonene, 1, 8-Cineole, (Z)-b-Ocimene, (E)-b-Ocimene, 6-Methyl-hept-5-en-2-one, verbanol, linalol and citronellol. Lemon grass leaf also contains nerolic and geranic acids (Dudai, 2001).

Among the several isolated and identified substances from the leaves of lemon grass, there are alkaloids, saponin, asistosterol, terpenes, alcohols, ketone, flavonoids, chlorogenic acids, caffeic acid, p-coumaric acid and sugars (Olaniyi *et al*., 1975; Hanson, 1976; Gunasingh and Nagarajan, 1981). Lemon grass leaf is also known to be rich in the flavonoid luteolin (Bricout and Koziet, 1978). Mien and Mohamed (2001) described the isolation of the flavonoids myrcene, quercetin, kaempferol and apigenine while Faruq (1994) obtained the phenolic compounds elemicin, catechol and hydroquinone.

Lemon grass leaf is also known to contain rich amounts of alcohols and esters. The geraniol is the most frequently isolated compound and is thought to be the main compound of plants of African origin corresponding to 40% of the essential oil composition (Faruq, 1994). An analytical study of the plant further revealed the presence of tannins, phosphates, nitrates and chlorets (Chisowa *et al.*, 1998). The major component of the non-saponifiable fraction of the light petroleum extract was found to be â-sistosterol, according to Olaniyi *et al*. (1975). Both authors also isolated a steroidal saponin, closely related to fucosterol, from the defatted plant material.

2.8.3 HEALTH BENEFITS OF CONSUMING LEMON GRASS LEAF

Infusion prepared from fresh or dry leaves of lemon grass is used in popular medicines across almost all continents and it comprises a wide range of indications. Equally wide is the spectrum use of substances extracted from lemon grass, especially of the essential oil. In India, it is used for gastrointestinal problems and, in China, as ansiolitic (Peigen, 1983). In the Mauricio islands and the Malay Peninsula, Lemon grass tea is commonly used against flu, fever, pneumonia, and to solve gastric and sudorific problems (Negrelle and Gomes, 2007).

In Nigeria, it is used as antipyretic, and for its stimulating and antispasmodic effects (Olaniyi *et al*., 1975). In Indonesia, the plant is indicated to help digestion, to promote diuresis, sweating and as emmenagogue (Hirschorn, 1983).

Lemon grass is also widely used in traditional medicine in Cuba and in many other countries of the Caribbean region. In Trinidad and Tobago it is used to combat diabetes (Mahabir and Gulliford, 1997). In Surinamese traditional medicine, lemon grass is used against coughing, cuts, asthma, bladder disorders and as a diaphoretic and to relieve headaches. Its popular use range is considerably wide, such as: restorative, digestive, anti-tussis, effective against colds, analgesic, antihermetic, anti-cardiopatic, antithermic, anti-inflammatory of urinary ducts, diuretic, antispasmodic, diaphoretic and antiallergic (Negrelle and Gomes, 2007). In the State of Parana, Lemon grass stands out in several ethnobotanical studies, being preferentially used as sedative (Jacomassi and Piedade, 1994). In Ghana, people drink Lemon grass infusions to cure ailments like fever and malaria. The plant also grows freely in backyards and gardens (Source: personal communication and observation).

2.8.4 RATIONALE FOR USING MORINGA, ROSELLE AND LEMON GRASS IN HERB TEA FORMULATIONS

Local consumption of 'Moringa tea' is increasing as a consequence of rising publicity about its health benefits (Newton, 2007). Roselle has been a desirable component of herb tea preparations because of its characteristic brightly coloured red infusions which consumers find attractive (Blench, 1997) as well as its unique flavour. Lemon grass leaves are used in food products to enhance their aromatic and flavor qualities (Figueirinha *et al.*, 2008). It is expected that blending the three herbs in the right proportions will produce a herb tea product with acceptable sensory properties.

2.9 SENSORY EVALUATION

Sensory evaluation is a scientific discipline used to evoke, measure, analyze and interpret reactions to those characteristics of food and materials as they are perceived by the senses of sight, smell, taste, touch and hearing. Sensory analysis, therefore, is indispensable and many food industries integrate this program in their research and development plan. In the measurement of sensory properties, two main types of sensory tests have been identified – analytical and consumer sensory tests (Stone *et al*., 1974).

2.9.1 Descriptive Sensory Analysis

Sensory profiling is a descriptive method that qualifies and quantifies organoleptic properties of products. In other words, sensory characterization of a food product begins with descriptive sensory evaluation that provides a pre-defining terminology for describing sensory perceptions as objectively as possible (Moskowitz, 1983). The terminology is, simply, a set of labels (descriptors) that a panel has agreed upon that enables them to fully describe the sensory properties of the products being evaluated.

Descriptive sensory analysis addresses some of the problems of language use, interpretation and scaling difficulties. To achieve this, a sensory quality program is organized where time and effort is taken to recruit and train panelists. This procedure also helps to obtain reliable data on the product being evaluated. Sometimes reference samples, if available, are used to calibrate the panel. In some cases, the terms may be selected from previously existing lists, in other cases they may be specifically generated by a panel of assessors (Stone *et al*., 1974).

Methods for generating descriptors are classified according to whether the results are qualitative or quantitative even though one could be transformed to another.

After the generation of descriptors, it is necessary to determine which of the descriptors sufficiently describe the product. Generally, methods employed for descriptor generation tend to yield many attribute sets many of which are unnecessary and therefore must be reduced to feasible size. This reduction should aim to identify those descriptors that are sufficient to describe the product fully, at the same time avoiding synonymous descriptors or characteristics that are difficult to quantify (Dura´ n *et al*., 1989; Johnsen and Kelly, 1990).

2.9.2 Training

Trained panelists have been used to carry out most of the methods put forward for vocabulary generation and assessment of products through sensory evaluation. Several standardization institutions recommend performing sensory profiling with a trained or an expert panel. This is necessary because training positions the panelists to adopt an analytical frame of mind. Conversely, untrained consumers tend to act non-analytically when scoring attributes (Lawless and Heymann, 1998). However, free choice profiling which does not require training of panelists has also been used successfully (Gains and Thomson 1990; Guy *et al*., 1989).

Recently, many authors have compared the performance of trained and untrained panels, presenting different conclusions. This is so because the studies in both situations varied significantly in terms of the nature and size of the covered product range, the methodology and the data analysis (Labbe *et al*., 2003). Many published studies have demonstrated lack of consensus on the impact of training on sensory descriptive analysis.

In the following publications authors showed that training really impacted on panel performance:

In a research conducted by Wolters and Allchurch (1994) where four different panels each made up of six to eight subjects assessed 16 oranges. It was found that training increased the number of discriminating and consensual attributes of the orange juices. The panels varied in duration of training and in the number of scored attributes (60 h/97 generated attributes, 30 h/70 generated attributes, 15 h/36 pre-defined attributes, 0 h/free choice profiling).

In a study conducted by Chollet and Valentin (2001), it was concluded that training increased the specificity and precision of the vocabulary of 12 beers. Samples were assessed by two different panels varying in size, duration of training and number of scored attributes (22 assessors/11 h/24 generated attributes, 18 assessors/0 h/22 generated attributes).

In a study conducted by Moskowitz (1996), the author found expertise to have no significant impact on product rating in a study of 37 sauces/ gravies for meat or pasta. Samples were assessed using the same predefined glossary (24 attributes) by two different panels varying in size and expertise (12 experts, 225 consumers).

Labbe *et al*., 2003, concluded that the lack of consensus may be due to the different methodologies which were adopted and the context (academic research, industry) within which the study was conducted. In a typical industry setting, Labbe *et al*., 2003, supported the fact that training indeed had an influence on the reliability of sensory profiling. In their study, untrained panel was made to assess eight soluble coffees, representative of a benchmarking study. Training sessions were organized for the subjects, after which they were asked to assess these products again. The results showed that training was indeed necessary. Interestingly, their findings agreed with those of Wolters and Allchurch (1994), Roberts and Vickers (1994), and Chollet and Valentin (2001).

Even though some authors have seen no impact on training, many agree that training is necessary in carrying out a descriptive sensory evaluation. Training, in fact, orients the minds

of the panel to have a common understanding of the meanings of the attributes selected and score products in a similar and objective way. For consumer acceptance untrained panel always provides reliable information since scoring is based on preference rather than description.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 SAMPLE COLLECTION

Fresh Moringa was harvested from Newman Farms in Kumasi, Ghana. Fresh lemon grass was harvested from Kwame Nkrumah University of Science and Technology (KNUST) Botanic Gardens in Kumasi. Both samples were harvested at about ten (10) cm from the tip of the leaves and in the case of Moringa this included leaves and petioles of the plant. All wilting and visibly diseased plant materials were removed. Dried Roselle samples were purchased from the open market in Kejetia, Kumasi, Ghana. The samples were identified at the Department of Horticulture, Faculty of Agriculture in the Kwame Nkrumah University of Science and Technology, Kumasi, Ghana.

3.2 SAMPLE PREPARATION AND STORAGE

All plant materials were carefully inspected and all foreign materials removed. The samples were then gently rinsed in tap water. Lemon grass leaves were cut into about three cm pieces using a stainless steel kitchen knife. Moringa and Roselle were not cut into pieces, and the leaf stalks of Moringa were not removed. The samples were spread thinly on paper and dried in a solar drier for five days at a peak temperature of 62 °C. After drying the samples were milled using an electric Binatone Blender (China, Model BLG401). Milling was performed for about 15 min. The blender was washed before and after milling of each sample. The milled material was sieved through an Aluminum sieve (2mm). Part of the sieved samples were stored in glass bottles with tight lids and labeled. Formulations were prepared from the rest and bagged in non-drip tea bags using an automatic tea bagging machine (Telesonic ST-101). Each tea bag contained approximately 2g of product. The tea bags were stored in glass

bottles with tight lids and labeled for sensory analysis. A summary of the sample preparation procedure is shown in Figure 3.1.

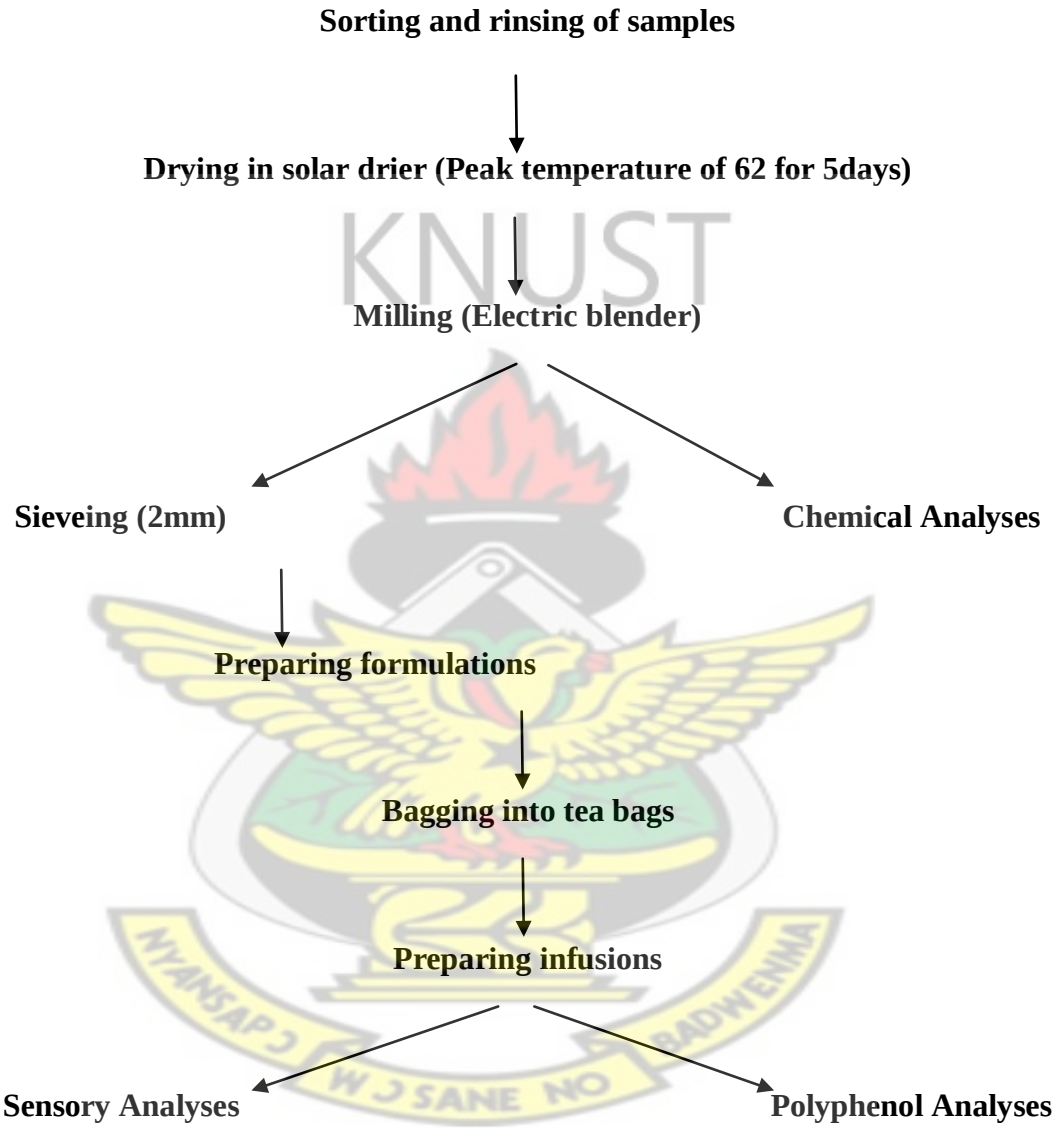


Figure 3.1 Flow diagram of sample preparation and process

3.3 CHEMICAL ANALYSES

Chemical analyses were performed on dried samples of Moringa, Roselle and Lemon grass using the Official Methods of Analyses (AOAC, 1990) and Pearson's Composition and Analysis of Foods (Kirk and Sawyer, 1997). The tests were moisture, total ash, minerals (Fe, Cu, Zn and Ca), crude protein, water insoluble ash and crude fibre. Other physicochemical tests were total polyphenolics, stalks, water soluble extractives, pH and light petroleum extracts. Three of the formulated products were further subjected to total polyphenolics tests. All analyses were carried out in triplicates.

3.3.1 DETERMINATION OF STALKS

This test was conducted solely on the Moringa leaf samples because Roselle calyces and lemon grass leaves did not contain any stalks. About 5 g of the sample was weighed and boiled for 15 min in a 1000 ml flat bottomed flask with 500 ml distilled water. The contents of the flask were transferred into a large plastic basin and the stalks were handpicked out of the basin with forceps. The leaves were dried in the drying oven at 100 °C for 5 h and left overnight till a constant weight was obtained and weighed. The stalks content was then determined by difference and expressed as a percentage of the initial sample weight (Kirk and Sawyer, 1997) using the formula as follows:

$$\textbf{\% Stalks} = \frac{\text{Initial weight of leaves} - \text{final weight of leaves}}{\text{Initial weight of leaves}} \times 100$$

3.3.2 DETERMINATION OF TOTAL POLYPHENOLICS

The extraction and determination of total polyphenolics followed the method of Makkar *et al.* (1993). This was performed in two stages: preparation of standard solution (using tannic acid) to produce a calibration curve; and preparation of polyphenol-containing water extract from the samples. The amounts of polyphenols in the samples were subsequently calculated as tannic acid equivalent from the tannic acid curve.

Preparation of standard solution

Fifty milliliters of 2 N Folin Ciocalteu reagent was diluted with an equal volume of distilled water in a 200 ml conical flask and stored in a brown bottle under refrigeration. About 40 g sodium carbonate was weighed and placed in a 200 ml conical flask. About 150 ml distilled water was added to the flask and swirled. The solution was topped up to the 200 ml mark with distilled water to obtain a 20% Sodium Carbonate Solution. About 0.1 g of pure tannic acid was weighed into a 100 ml volumetric flask and made to the mark with distilled water. The solution was gently swirled for 5 min. About 10 ml of the resulting solution was pipetted into another 100 ml volumetric flask and again made to the mark with distilled water.

Successive quantities of the tannic acid solution were pipetted into test tubes. Distilled water, Folin reagent and sodium carbonate solution were measured and added to the tannic acid solutions in the test tubes. The resulting solutions were swirled gently for 5 min. Absorbance of the solutions were measured at 725 nm using the Spectrophotometer 259 (Sherwood). The values obtained were used to `plot a standard tannic acid curve.

Preparation of polyphenol-containing water extract

About 2 g of the herb samples was weighed and placed in a 250 ml conical flask. About 150 ml of boiling water was transferred into the conical flask. The liquid was then filtered after 5

min and allowed to cool. About 1 ml of the filtrate was transferred into a test tube and the volume was made up to the 5 ml mark with distilled water. About 2.5 ml of the Folin reagent (1N) and 12.5 ml of the sodium carbonate solution (20%) were added (to establish an alkaline medium for the reaction) in the test tube. The solution was mixed by gently swirling the test tube for 5 min and allowed to stand for 40 min. The absorbance was read at 725 nm using the Spectrophotometer 259 (Sherwood).

This assay is based on the principle that phenols or phenolic compounds react with phosphomolybdic acid in Folin-Ciolcalteau reagent in alkaline medium, to produce a blue coloured complex (molybdenum blue), which absorbs in the UV-Visible region. The polyphenol content of each sample is calculated as tannic acid equivalent of the sample on a moisture-free basis:

$$\textbf{Conc (mg/g)} = \frac{\text{Conc (mg/ml)} \times \text{FV} \times \text{DF}}{\text{Sample weight}}$$

Where;

FV = final volume
DF = dilution factor

3.3.3 DETERMINATION OF WATER-SOLUBLE EXTRACTIVES (WSE)

Two grams (2 g) of the sample was refluxed with 100 ml distilled water for 1 hr. The sample was then filtered into a 250 ml volumetric flask using filter paper in a funnel. The residue inside the filter paper was returned to the boiling flask, and boiled with further 100 ml water for 30 min. The contents of the boiling flask were again filtered into the volumetric flask, and the residue washed thoroughly with hot water. The filtrate was made to the 250 ml, swirled gently, and 50 ml of it was pipetted into a clean and weighed moisture crucible, and dried in an oven at 100 °C for 12 h. The crucible and its contents were then cooled in a desiccator and

reweighed. The results were calculated as a percentage of the sample on a moisture free basis (Kirk and Sawyer, 1997):

$$\textbf{\% WSE} = \frac{\text{Weight of crucible contents}}{\text{Weight of the sample}} \times 100$$

3.3.4 DETERMINATION OF LIGHT PETROLEUM EXTRACT (LPE)

Two grams (2 g) of each sample was put in a paper thimble and plugged with cotton wool. The thimble was placed in a soxhlet extraction apparatus and extracted with light petroleum ether (boiling point 40 – 60 °C) at low heat for 5 hrs in a continuous extraction manner. The extract was collected in a flask and dried at 100 °C for 30 min, cooled in a dessicator and weighed (Kirk and Sawyer, 1997). The percent light petroleum extract (LPE) was calculated as follows:

$$\textbf{\% LPE} = \frac{\text{Weight of extract}}{\text{Weight of sample}} \times 100$$

3.4 PREPARATION OF FORMULATIONS

The three dried and milled herbs were mixed in varying proportions to obtain nine different formulations (Table 2.3). The proportions were obtained using Design Expert (2007). Two gram samples of each formulation were bagged in rectangular infusion tea bags (5cm × 4cm). Commercial Moringa herb tea (Newman Farms Ltd) was used as control. All bagged samples were stored in glass jars at between 28 °C and 34 °C away from sunlight. They were labeled accordingly for sensory analyses.

Table 2.3 Proportion of herbs in blended products

Product code	*Moringa* leaves (%)	Roselle calyces (%)	Lemon grass leaves (%)
721	70	20	10
712	70	10	20
755	70	15	15
631	60	30	10
622	60	20	20
613	60	10	30
532	50	30	20
523	50	20	30
553	55	15	30
591 (control)	100	0	0

3.5 SENSORY EVALUATION

Sensory evaluation was carried out in two phases – acceptance tests and descriptive tests. In the first phase, acceptance tests were conducted on ten (10) sample infusions using fifty (50) untrained panelists. The second phase consisted of descriptive tests on three (3) selected samples using nine (9) trained panelists. Randomized complete block design was used for the descriptive tests with the order of serving of the samples randomized to prevent any biasing effect.

3.5.1 PREPARATION OF INFUSIONS

Infusions were prepared from all bagged samples including the control. Ten (10) bags of each sample formulation were placed in a glass jar and boiling water (1.5l) was poured into the jar. Mineral water (Voltic) was used. The formulations were allowed to infuse for 5 min. The bags were then removed from the infusions. The infusions were unsweetened.

3.5.2 ACCEPTANCE TEST

3.5.2.1 Selection of panelists

Fifty (50) panelists (32 female; 18 male) were recruited from KNUST campus for the acceptance tests. Panelists were mostly students aged between 18 and 24 years with few university staff. The number of panelists was decided based on sensory evaluation guidelines (IFT 1981), which indicates that for a sensory evaluation method of preference and/or acceptance and/or opinions of a product, there is no recommended 'magic number' – the minimum is generally 24 panelists, which is sometimes considered rough product screening; 50 – 100 panelists are usually considered adequate. Panelists were chosen on the basis of their willingness and commitment to partake in the sensory evaluation, availability and familiarity with tea in general or herb tea in particular. They were neither trained nor given prior information about the constituent ingredients from which the infusions were prepared.

3.5.2.2 Procedure for serving tea to panelists

Sample infusions were three-digit coded and served randomly to panelists. About 30 ml of each infusion was served in a 50 ml transparent cup. One sample was served at a time. Panelists were free to analyze the samples in any order of their choice. Panelists were discouraged from conferring among one another during the analyses.

The sample infusions were approximately 60 °C to 70 °C at the time of tasting. Panelists were required to rinse their mouths with warm water (about 60° C) before the commencement of tasting. To minimize possible carry-over effects, panelists were required to rinse their mouths thoroughly with warm water (about 60°C) after each tasting and wait 90 s before tasting the next sample. Panelists were not required to swallow all 30 ml of each sample;

however they were asked to hold about 10 ml sample in the mouth for 5 s and swallow small quantities in order to appreciate the full sensory character of the beverage. Panelists were allowed to repeat tasting where necessary.

The tests were carried out in two sessions, separated by a 24-hour period. This was to prevent likely panelist fatigue due to the large number of samples. Each session started at 10.00am and lasted for approximately 1.5 h. In both sessions, all ten tea samples were presented to all panelists. Each panelist was free to select any five samples of their choice for evaluation. During the second session, each panelist was asked to continue with analyses of the remaining five samples. Sessions took place in the College of Science Chemistry Laboratory, KNUST, Ghana.

3.5.2.3 Scoring of samples

The panelists were instructed to score their acceptance for 6 attributes of the infusions: colour, aroma, flavor, aftertaste, astringency and overall acceptability. Where a panelist did not clearly understand the meaning of a particular attribute, explanation was provided. The panelists scored their acceptance of the attributes using a 5-point hedonic scale with 1 meaning 'dislike very much' and '5' meaning 'like very much'. From the results of the acceptance tests, two formulations were selected in addition to the control for further descriptive tests.

3.5.3 DESCRIPTIVE TEST

3.5.3.1 Selection of panelists

Eleven (11) people were initially recruited as panelists for descriptive tests. However, only nine (9) panelists underwent the full training and took part in the main sensory evaluation.

Out of the nine, seven (7) were undergraduate students while the remaining were postgraduate students from Department of Biochemistry or Food Science and Technology. They included six (6) females and three (3) males with an age range of 21 to 34 years. All panelists for descriptive tests had participated in at least two descriptive analyses of a beverage and were regular consumers of tea.

3.5.3.2 Training of panelists

Panelist training consisted of research orientation, familiarization of panelists with test procedures, calibration of panel using reference samples for green tea, development, definition and grouping of descriptors. Training duration was approximately 9 h over a 3-day period.

Research orientation

Panelists were given an introduction to the research and purpose of the study. They were further informed that a descriptive vocabulary needed to be developed for herb tea. Panelists were taken through the basic principles of sensory evaluation. This session lasted for approximately 1 h.

Calibration of Panel and familiarization with test procedures

Panelists were calibrated using reference samples for green tea (Chambers and Lee 2007) (Table 3.1). The panel was introduced to the 15-point numerical scale where '0' represents 'weak' and '15' represents 'strong' (Munoz and Civille, 1998). Most of the panel members were familiar with this test procedure. This lasted for approximately 4 h.

Table 3.1 Reference samples for green tea

Sensory attribute	Reference
Sweet taste	0.1% sucrose
Sour taste	0.035% citric acid
Bitter taste	0.05% caffeine
Astringency	0.1% tannic acid

Source: Chambers and Lee (2007)

Development, definition and grouping of descriptors, and generation of references

General procedures for developing definitions and references were adapted from the flavor profile method (Caul, 1957; Keane, 1992).The panel leader instructed the panelists to make individual notes on descriptors for the sensory attributes of the herb teas. After all the panelists were done, the panel leader then led a discussion to reach agreement on the descriptors present in the herb tea samples. Once the panel came to an agreement on the descriptors, a concise definition was provided for each descriptor. Synonymous descriptors were identified and eliminated. The panelists also provided references for each descriptor. As much as possible, panelists attempted to use reference products that were representative and exhibiting a specific attribute as suggested by Piggott (1991). Specific attention was given to references because they can be used to overcome communication difficulties (Barcenas *et al.*, 1999), are helpful in lowering judge variability, allow calibration of the panel in the use of intensity scale (Stampanoni, 1994) and help reduce the time needed to train a panel (Rainey, 1986). This session lasted for approximately 4 h.

3.5.3.3 Main Sensory Evaluation

In the main experiment, the panelists evaluated the sensory characteristics of the herb tea based on the descriptors generated during training. The appearance attributes were evaluated first followed by the aroma, flavour and mouthfeel attributes. The three products were presented to each subject in the order based on a randomized complete block design to prevent any biasing effect. Sessions took place in the College of Science Chemistry Laboratory, KNUST. All samples were three-digit coded and served in 50 ml transparent glass cups. Panelists were instructed to measure each of the defined descriptors in the herb teas using a 15-point numerical scale where '0' represents 'weak' and '15' represents 'strong' (Munoz and Civille, 1998). The products were scored in triplicates.

3.6 STATISTICAL ANALYSIS

GraphPad Prism 5 and Excel (2007) were used to carry out Analysis of Variance (ANOVA) on the data and graphical representation of the results. Where variations were observed among the samples at 5% statistical significance, Post-hoc tests (Turkey) were carried out to determine the sources of variation.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 CHEMICAL ANALYSIS OF HERB SAMPLES

4.1.1 MOISTURE CONTENT

The initial moisture contents of the freshly harvested Moringa and Lemon grass samples were 74.38% and 65.27% respectively. The Roselle, which was obtained partially dried, had an initial moisture content of 17.93%. After drying in the solar drier, Roselle retained the highest average moisture content of 8.57% followed by Moringa with 6.86% and Lemon grass having the least moisture content of 6.17% (Figure 4.1). All the values were significantly different ($P < 0.05$). The differences in moisture content of the dried samples may be attributable to differences in structure of the samples. Roselle calyx is fleshy and cup-shaped in nature (Blench 1997; Ali *et al*. 2005) implying reduced surface area. It may therefore have allowed the least penetration of heat during drying hence the relatively high moisture content after drying. It is therefore necessary to process Roselle into a form that allows for better drying. Moreover, alternative methods need to be explored for drying Roselle. Lemon grass leaf is comparatively longer and has a wider surface area than Moringa leaf. This may have accounted for its relatively low moisture content than Moringa. According to Fennema (1996), moisture content bears a relation with the shelf stability of a food product in that the higher the moisture content, the lower the shelf stability and vice versa. Tea in excess of 11% moisture is liable to mould infestation and musty infusion (Kirk and Sawyer, 1997). The samples were however within the recommended moisture range of 6.1% to 9.2% (Kirk and Sawyer, 1997).

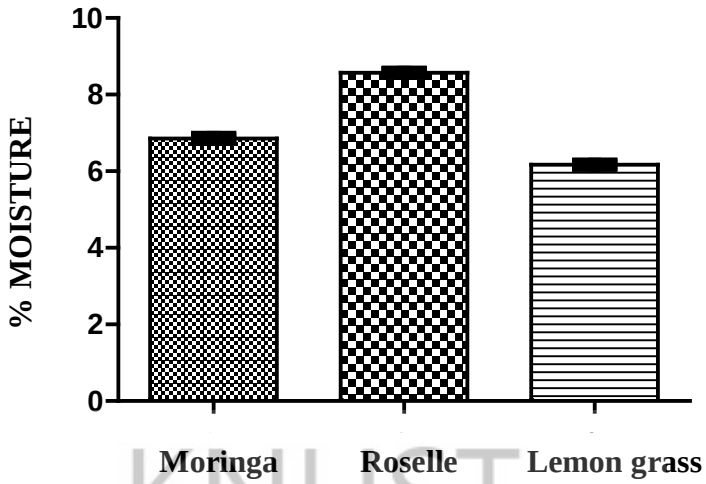


Figure 4.1 Moisture content of herb samples (Error bars indicate SEM at 5% probability; n=3)

4.1.2 CRUDE ASH CONTENT

Crude ash content refers to the total mineral composition of a sample. Moringa had the highest ash content of 8.57% followed by Roselle with 6.79%, while lemon grass had the least ash value of 6.09% (Figure 4.2). All the values were significantly different ($P < 0.05$). The ash value of Moringa leaf was lower than ash values reported by Fuglie (2001) of three dried Moringa leaf samples obtained from plants cultivated in three separate regions – Nicaragua, Niger and India. The samples showed respective ash values of 8.9%, 9.4% and 11.8%. These differences in ash value may be attributable to differences in the mineral composition of the soils within which they were cultivated. The ash value of Roselle was approximately the same as reported value of 6.8% by Babalola (2000). The dry weight moisture content values of the lemon grass and Roselle samples were within the recommended range of 5.2% to 7.2% for teas (Kirk and Sawyer, 1997).

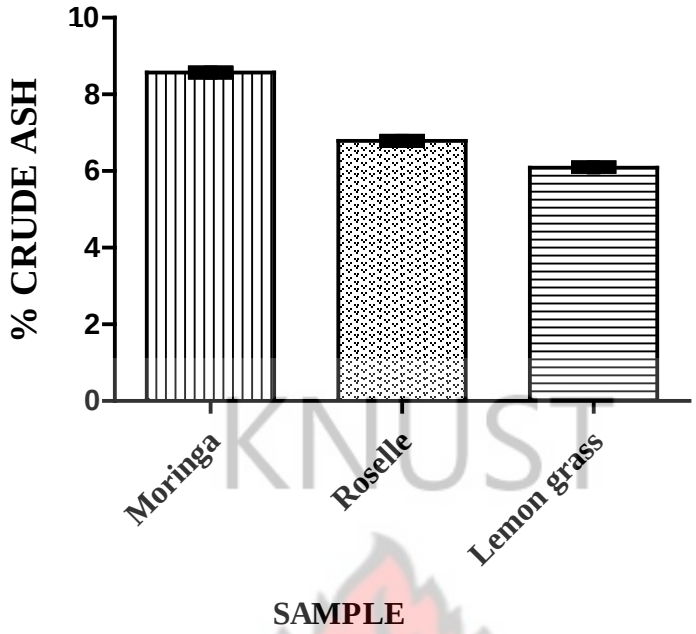


Figure 4.2 Crude ash content of herb samples (Error bars indicate SEM at 5% probability; n=3)

4.1.3 MINERAL CONTENT

Calcium Content

The Calcium (Ca) content of the dried samples was relatively high compared to the other minerals analyzed. Moringa leaf contained the highest Ca content of 412.5 mg/100g which was more than twice that of Lemon grass leaf (149.1 mg/100g). The Ca content of Roselle (294.6 mg/100g) was the equivalent of about one third the recommended daily intake of 1000 mg (Jensen, 2000). The results showed that the herb samples were generally good sources of Ca. All the values were however statistically different ($P < 0.05$) (Figure 4.3). Besides their nutritional significance, minerals may also influence the sensory character of beverages. According to Fennema (1996), Calcium in foods is mostly present as $Ca(OH)_2$, forming Ca^{2+} and OH^- ions in aqueous solution. Because these ions are alkaline, they increase the pH of the solution, making the solution less acidic and therefore less sour.

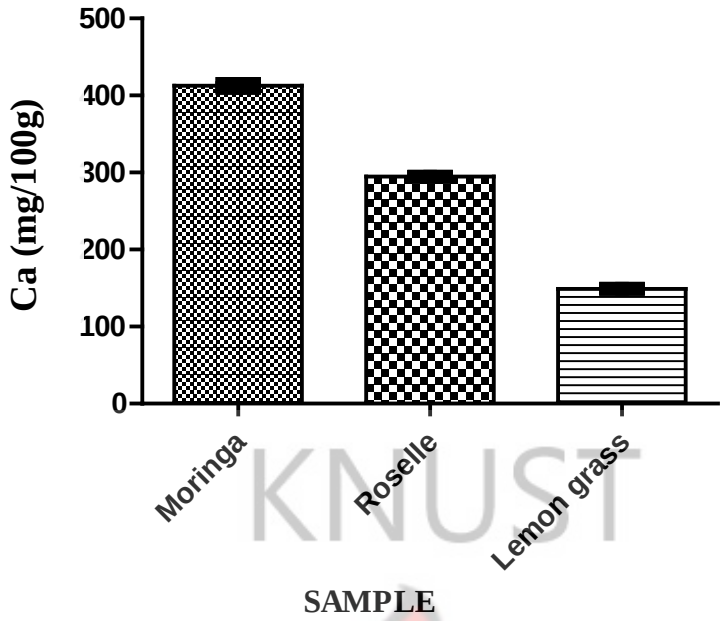


Figure 4.3 Calcium content of herb samples (Error bars indicate SEM at 5% probability; n=3).

Iron Content

Iron (Fe) is an essential macronutrient required for human growth. The concentration of Fe in Roselle calyx (24.26 mg/100g) was about twice that in Moringa leaf (12.93 mg/100g) and Lemon grass leaf (11.58 mg/100g) (Figure 4.4). All the values were significantly different ($P < 0.05$). The value of Roselle was lower than the reported value of 34.6mg/100g by Babalola (2000) and 83.3 mg/100g by Nnam and Onyeke (2003). Further, the Fe content of Moringa leaf was higher than reported value of 9.82 mg/100g by Tetteh (2008). Generally, differences in plant mineral composition may be attributed to differences in mineral composition of the soils within which the plants were cultivated, which may be affected in turn by cultural practices such as fertilizer application. The results show that the three samples are good sources of Fe. This is because the values are comparable to Recommended Daily Allowance

of Fe – 10 mg/100g to 13 mg/100g for children; 7 mg/100g for men; and 12 mg/100g to 16 mg/100g for women and breast feeding mothers (Fuglie, 2001).

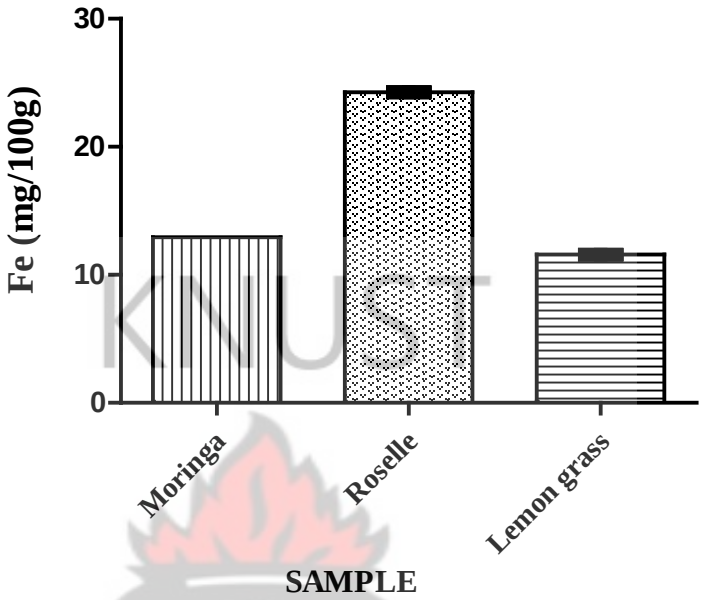


Figure 4.4 Iron content of herb samples (Error bars indicate significant differences at 5% probability; n=3)

Copper Content

Copper is an essential micronutrient needed for normal human metabolism. Recommended dietary allowances range from 1.5 to 2.0 mg per day for adults (Sandstead, 1982). The herb samples were however low in copper content. The Lemon grass sample recorded the least value of 0.58 mg/100g as compared to the Roselle sample which had 0.69 mg/100g and Moringa with 0.94 mg/100g (Figure 4.5). Since the copper content of the samples was below the recommended daily requirement, it is important to supplement copper needs from other dietary sources.

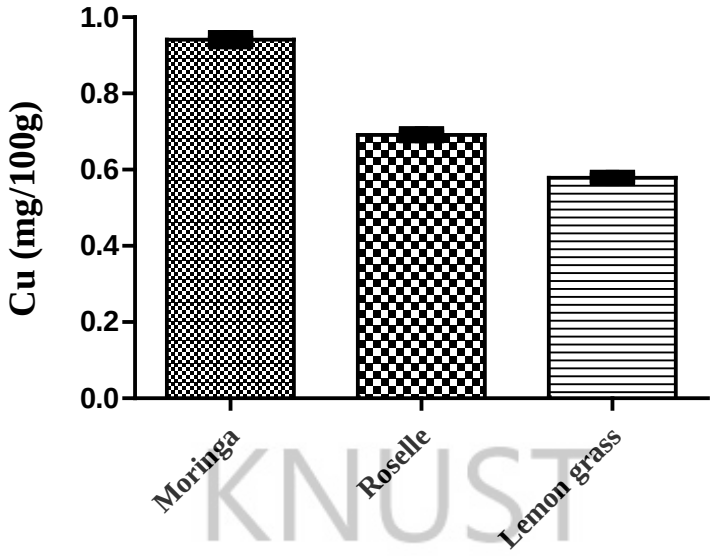


Figure 4.5 Copper content of herb samples (Error bars indicate SEM at 5% probability; n=3)

Zinc Content

Zinc is an essential micronutrient for human growth, development and maintenance of immune function, which enhances prevention and recovery from infectious diseases (Black, 2003; Walker *et al.*, 2005). The average recommended dietary allowance of zinc is 6 mg per adult per day (Smith *et al.*, 1983). Meat products are the best sources of Zn (Walker *et al.*, 2005), and consequently, Zn deficiencies are usually found in populations which consume diets with insufficient amounts of animal-source foods. Moringa had the highest composition of Zn (2.06 mg/100g) while Lemon grass had the least composition (1.82 mg/100g) (Figure 4.6). The results imply that the three herbs, particularly Moringa, could be used as a cheap source of zinc in diet formulation.

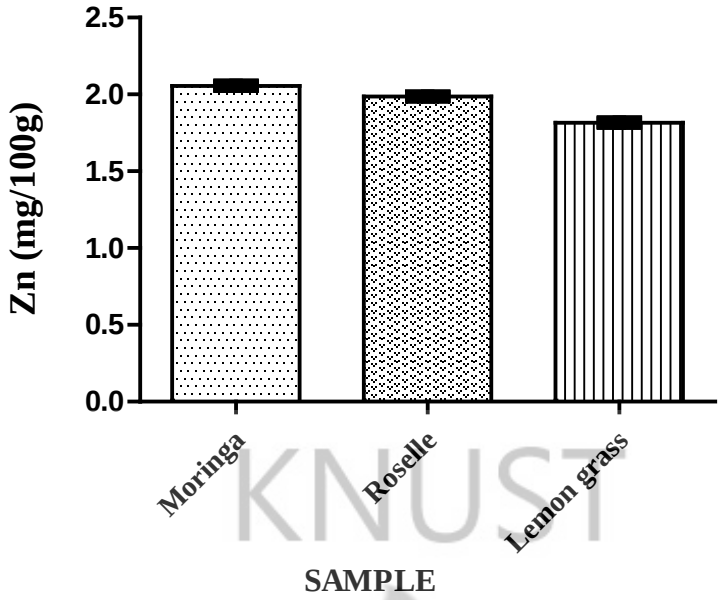


Figure 4.6 Zinc content of herb samples (Error bars indicate SEM at 5% probability; n=3)

4.1.4 CRUDE PROTEIN CONTENT

The Moringa sample had the highest crude protein content of 26.59% while Roselle and Lemon grass samples had values of 8.59% and 7.23% respectively (Figure 4.7). All the values were significantly different ($P < 0.05$). These values are comparable to reported values of 27.1% for Moringa (Booth and Wickens, 1988) and 8.6% for Roselle (Babalola, 2000). The high crude protein value of Moringa is corroborated by Fuglie (2001) who reported further that the protein digestibility of Moringa is high (85% to 90%). Crude protein bears an indirect relationship to the sensory character of tea. This is because amino acids, which are the building blocks of proteins, have been shown to produce off-flavours in tea (Kinugasa *et al.*, 1997).

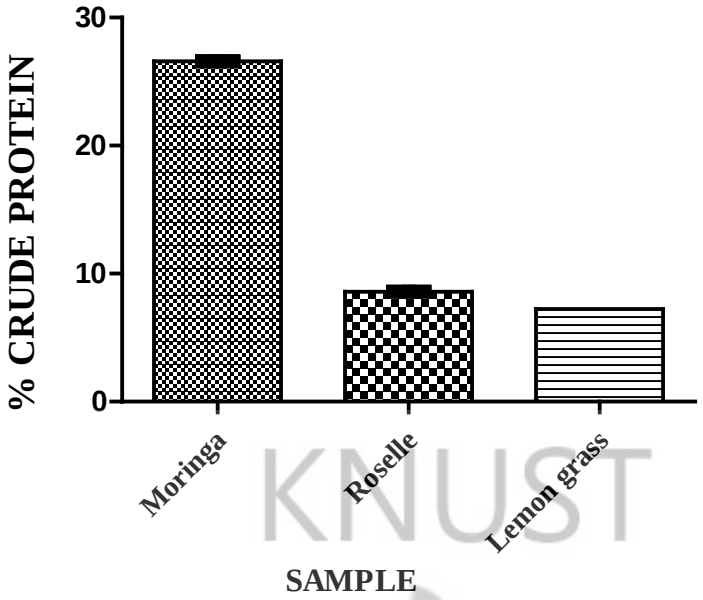


Figure 4.7 Crude protein content of herb samples (Error bars indicate SEM at 5% probability; n=3)

4.1.5 CRUDE FIBRE CONTENT

The Lemon grass sample had the highest crude fibre content of 21.38% followed by the Moringa sample with 19.64%. Roselle had the least value of 10.02% (Figure 4.8). All the values were significantly different ($P < 0.05$). Crude fibre in the diet generally serves to enhance the efficiency of digestion by stimulating peristaltic action and thereby enhancing the movement of food through the alimentary canal. It is also known to prevent colon cancer (BeMiller and Whistler, 1999). In tea, however, crude fibre improves the sensory appeal of the beverage by providing a filter system to prevent the leaching of plant material from the tea bag into the infusion (Waldron *et al.*, 2003).

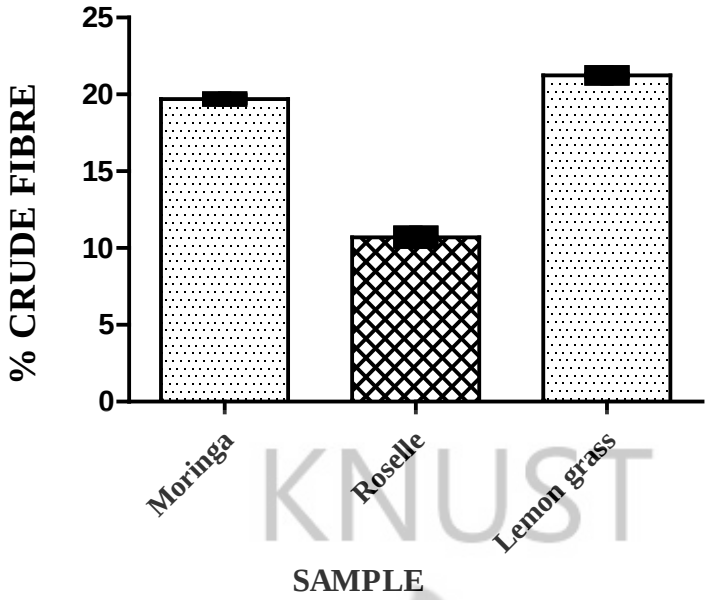


Figure 4.8 Crude fibre content of herb samples (Error bars indicate SEM at 5% probability; n=3)

4.1.6 WATER SOLUBLE EXTRACTIVES (WSE)

The WSE indicates the percentage of extractives that can be dissolved in infusion during brewing of tea (Kirk and Sawyer, 1997). For a herb tea containing more than one herb ingredient, the ingredient with the highest WSE will exert the greatest influence on the character of the infusion. From the results, the WSE value of Roselle calyx (12.38%) was about three times that of Lemon grass leaf (4.07%) and almost twice that of Moringa leaf (7.44%) (Figure 4.9). All the values were significantly different ($P < 0.05$). The high WSE of Roselle calyx may be due to its rich water-soluble anthocyanin pigments (Du and Francis 1973; Mazza and Miniati 2000). The observation is further supported by Wong *et al*., 2002, who reported that hot water extraction is an effective method of calyx anthocyanin extraction in Roselle. By inference, Roselle will generally exert stronger influence on the properties of herb tea.

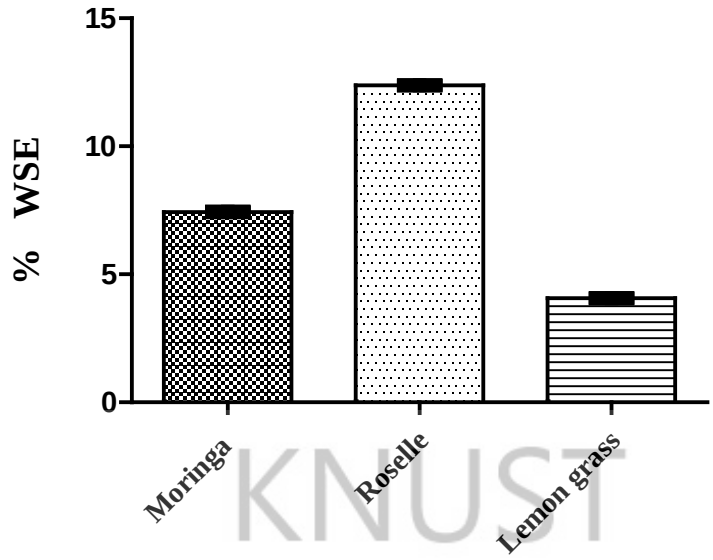


Figure 4.9 Water soluble extractive (WSE) of herb samples (Error bars indicate SEM at 5% probability; n=3)

4.1.7 LIGHT PETROLEUM EXTRACTIVES (LPE)

Lemon grass sample had the highest LPE value of 4.1% followed by Moringa with 3.48%. Roselle sample had the least value of 2.71% (Figure 4.10). All the values were significantly different ($P < 0.05$). The high LPE of Lemon grass leaf may be attributable to its rich aromatic essential oils (Chisowa *et al.*, 1998). By inference, Lemon grass will impart pleasant aroma to herb tea.

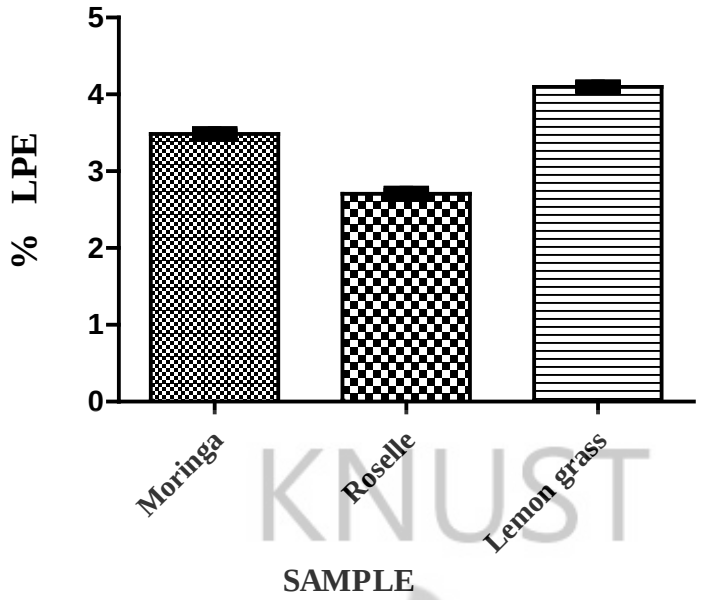


Figure 4.10 Light petroleum extractive (LPE) of herb samples (Error bars indicate SEM at 5% probability; n=3)

4.1.8 pH

The Roselle sample had the least pH value of 2.73 while the Lemon grass and Moringa samples had pH values of 4.53 and 5.47 respectively (Figure 4.11). All the values were significantly different ($P < 0.05$). From the results, Moringa and Lemon grass samples were lowly acidic while the Roselle was highly acidic. Infusions from Moringa leaves were slightly acidic probably due to the high content of heavy metals or constituent oxalic, phenolic and chlorogenic acids (Fuglie, 2001). The finding confirms reports that Roselle calyx is rich in organic acids (Kerharo, 1971, Wong *et al*. 2002). The pH of a sample affects the sensory character of the sample. Low pH results in sour and astringent products. By implication, Roselle as an ingredient in herb tea will potentially impart greater sourness than Moringa and Lemon grass.

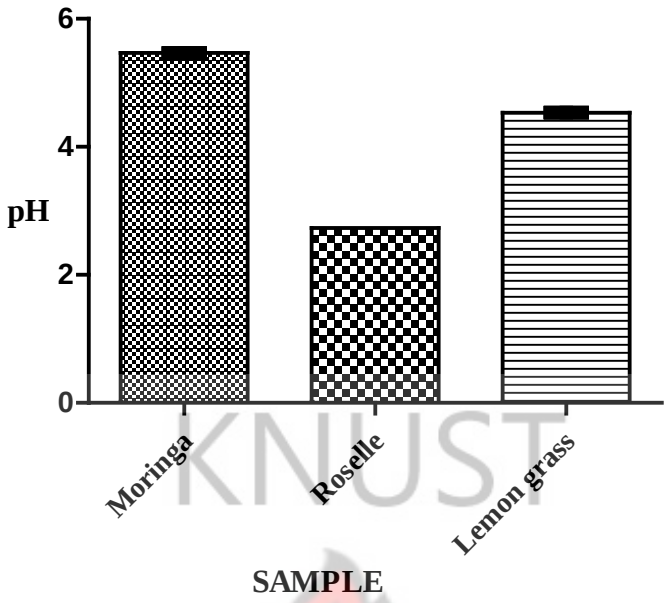


Figure 4.11 pH of herb samples (Error bars indicate SEM at 5% probability; n=3)

4.1.9 STALKS

The stalk content gives an indication of the proportion of leaf stalks that a tea ingredient contains in relation to actual leaves. The stalk content for Moringa leaf was 7%. This falls within the range recommended by Kirk and Sawyer (1997) who reported that the proportion of stalks in tea should preferably be below 25%. Roselle calyx and Lemon grass leaf did not contain any stalks.

4.1.10 TOTAL POLYPHENOL CONTENT (TPC)

The polyphenol content of ingredients in herb tea formulation is important because it gives a direct indication of the health-enhancing property of the herb. Moringa leaf recorded the highest total polyphenol content (TPC) of 35.70 mg/g followed by Roselle with 27.81 mg/g.

Lemon grass had the least TPC of 15.37 mg/g (Figure 4.12). All the values were significantly different ($P < 0.05$). Bajpai *et al.* (2005) reported TPC values of 20.9 mg/g for Moringa leaves using 50% methanol: water extract. This implies that hot water extraction (100 °C) proved to be a more efficient means of total polyphenol extraction. The values compare well with the TPC of other plants commonly used in herb teas such as leaves of *Cinnamomum tamala* (12.5 mg/g), *Matricaria charantina* (15.9 mg/g) and *Piper longum* leaves (18.1 mg/g) (Bajpai *et al.*, 2005).

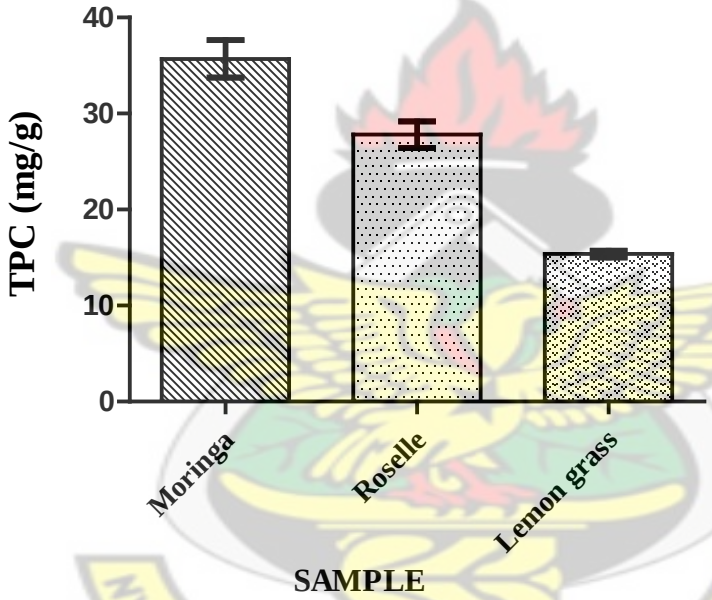


Figure 4.12 Total polyphenol content (TPC) of herb samples (Error bars indicate SEM at 5% probability; n=3

4.2 ACCEPTANCE TESTS

4.2.1 COLOUR

Consumer appetite for food is stimulated or dampened by its colour. This is because the colour of food indicates the flavour of food (Downham and Collins, 2000). Product **532** brewed infusions with the most preferred colour (3.9), followed by products **631** (3.82), **523** (3.30), **622** (3.18) and **613** (3.12) in that order (Figure 4.15). From the trend the three most preferred products (**532**, **631** and **523**) contained high proportions of Roselle (30% and 20%). Conversely, the three least preferred products (the **control**, **712** and **755**) contained the least proportion of Roselle (0%, 10% and 15%). This indicates that products with higher proportions of Roselle brewed infusions with a more appealing colour. Roselle infusion has been described as a red, transparent, liquid (Dominguez-Lopez *et al.*, 2008) which many people find attractive (Blench, 1997). Roselle is also known as Red Sorrel due to the unique red colour of its calyx (Mounigan and Badrie, 2006). Researchers (Du and Francis 1973; Mazza and Miniati 2000) have attributed the reddish colour of Roselle calyx to the presence of anthocyanins – highly water-soluble, brilliantly red pigments. The mean score for colour for product **532** was significantly different ($P < 0.05$) from that of all the other products except **631**. There were however no significant differences ($P > 0.05$) between colour scores of products **721** (2.94), **712** (2.78), **755** (2.84), **622** (3.18), **613** (3.12), **553** (2.98) and **591** (control) (2.68).

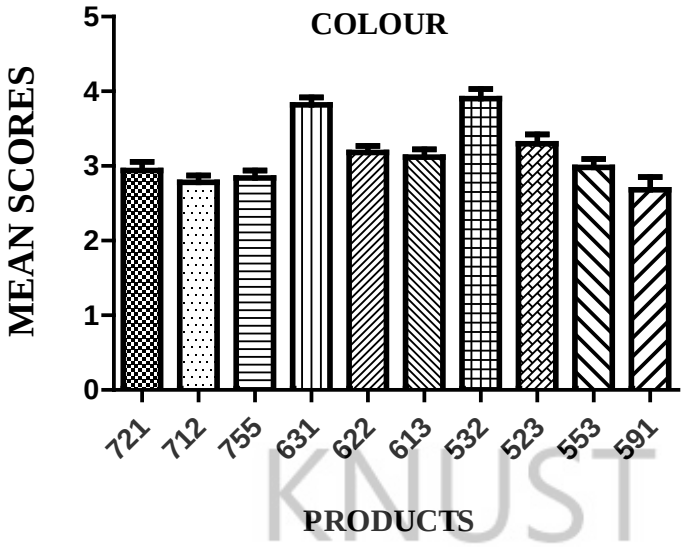


Figure 4.13 Panelist scores of acceptance test for colour (Hedonic scale of 1 to 5; where 5 represents 'like very much' and 1 represents 'dislike very much'. 721 (70% Moringa + 20% Roselle + 10% Lemon grass); 712 (70% Moringa + 10% Roselle + 20% Lemon grass); 755 (70% Moringa + 15% Roselle + 15% Lemon grass); 631 (60% Moringa + 30% Roselle + 10% Lemon grass); 622 (60% Moringa + 20% Roselle + 20% Lemon grass); 613 (60% Moringa + 10% Roselle + 30% Lemon grass); 532 (50% Moringa + 30% Roselle + 20% Lemon grass); 523 (50% Moringa + 20% Roselle + 30% Lemon grass); 553 (55% Moringa + 15% Roselle + 30% Lemon grass); 591 (100% Moringa). Error bars indicate SEM at 5% probability; n=50**)**

4.2.2 AROMA

Panelists showed the highest preference for the aroma of product **523** (3.96), followed by **532** (3.94), **613** (3.76), **553** (3.54) and **622** (3.52) in that order (Figure 4.16). Four blends with the least proportions of Roselle and Lemon grass (**591**, **755**, **712** and **721**) were also the least preferred in aroma. Because of reports of high concentration of aromatic oils in Lemon grass (Baratta *et al.*, 1998; Kasali *et al.*, 2001), it was expected that samples with higher proportions of Lemon grass would record higher mean scores for aroma. Even though most of the scores followed this trend, there were few exceptions. One exception was product **532** which contains only 20% Lemon grass, but was more preferable in aroma to **613** and **553** which both contain 30% Lemon grass. A possible explanation to this unexpected result is that the high Roselle content (30%) in **532** may have produced a synergistic effect with the Lemon grass component, thereby resulting in its unexpected high aroma preference. The

mean score of product **523** was significantly different ($P < 0.05$) from those of all the other products except products **613** and **532.** The mean scores for aroma were not significantly different ($P > 0.05$) for products **721** (2.70), **712** (2.72), **755** (2.68), **631** (2.88) and the **591** (**control**) (2.66).

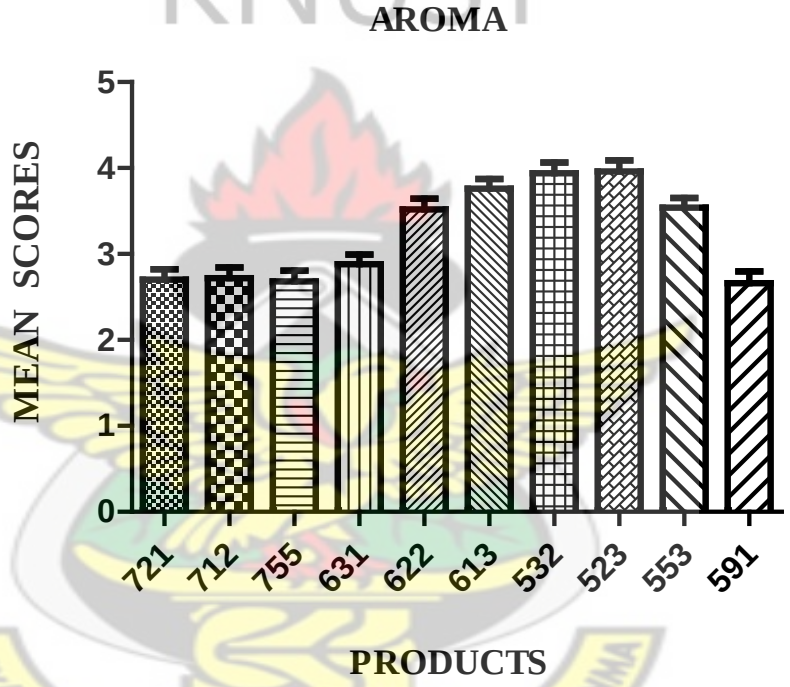


Figure 4.14 Panelist scores of acceptance test for aroma (Hedonic scale of 1 to 5; where 5 represents 'like very much' and 1 represents 'dislike very much'. 721 (70% Moringa + 20% Roselle + 10% Lemon grass); 712 (70% Moringa + 10% Roselle + 20% Lemon grass); 755 (70% Moringa + 15% Roselle + 15% Lemon grass); 631 (60% Moringa + 30% Roselle + 10% Lemon grass); 622 (60% Moringa + 20% Roselle + 20% Lemon grass); 613 (60% Moringa + 10% Roselle + 30% Lemon grass); 532 (50% Moringa + 30% Roselle + 20% Lemon grass); 523 (50% Moringa + 20% Roselle + 30% Lemon grass); 553 (55% Moringa + 15% Roselle + 30% Lemon grass); 591 (100% Moringa). Error bars indicate SEM at 5% probability; n=50**)**

4.2.3 FLAVOUR

The product which brewed infusions with the most preferred flavour was **532** (3.88) followed by **523** (3.60), **553** (3.24), **631** (2.80) and **622** (2.72) in that order (Figure 4.17). Infusions from **591** (control) recorded the lowest score in flavor (2.36). From the trend, products with high proportions of Moringa and low proportions of Roselle and Lemon grass were less preferable. Conversely products with low proportions of Moringa and high proportions of Roselle and Lemon grass had a more appealing flavour. This observation is consistent with the trend of scores for aroma. However, unlike aroma which was influenced mainly by the proportion of Lemon grass, flavour was influenced more by Roselle. Thus product **532** (3.88) was preferable to **523** (3.60) because the former contains higher Roselle (30%) than the latter (20% Roselle). Similarly, product **523** (3.60) was preferable to **553** (3.24), and product **553** (3.24) was preferable to **631** (2.80). The mean score of product **532** was however significantly different ($P < 0.05$) from those of all the other products except that of **523**. There were no significant differences ($P > 0.05$) in the mean scores of products **721** (2.38), **712** (2.38), **755** (2.42), **613** (2.68) and **591** (control) (2.36).

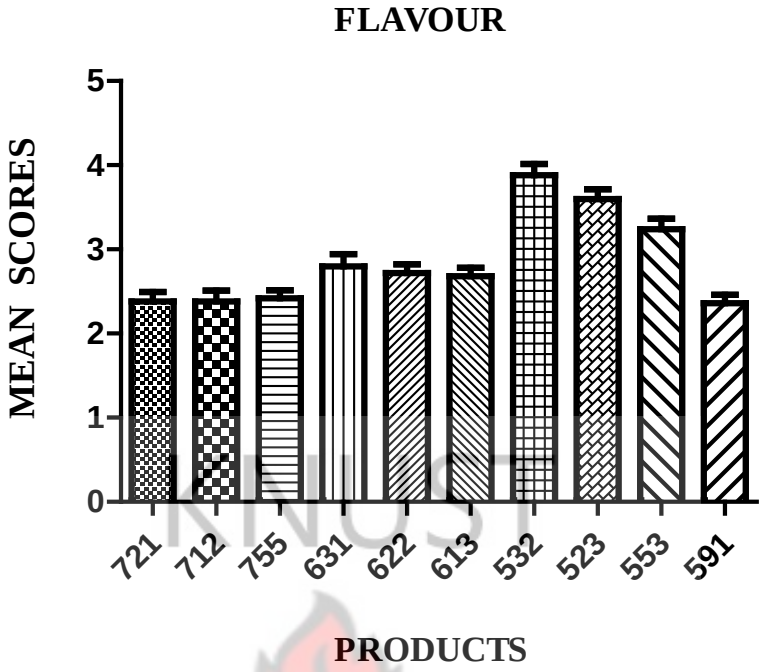


Figure 4.15 Panelist scores of acceptance test for flavour (Hedonic scale of 1 to 5; where 5 represents 'like very much' and 1 represents 'dislike very much'. 721 (70% Moringa + 20% Roselle + 10% Lemon grass); 712 (70% Moringa + 10% Roselle + 20% Lemon grass); 755 (70% Moringa + 15% Roselle + 15% Lemon grass); 631 (60% Moringa + 30% Roselle + 10% Lemon grass); 622 (60% Moringa + 20% Roselle + 20% Lemon grass); 613 (60% Moringa + 10% Roselle + 30% Lemon grass); 532 (50% Moringa + 30% Roselle + 20% Lemon grass); 523 (50% Moringa + 20% Roselle + 30% Lemon grass); 553 (55% Moringa + 15% Roselle + 30% Lemon grass); 591 (100% Moringa). Error bars indicate significant difference at 5% probability; n=50**)**

4.2.4 AFTERTASTE

Differences in aftertaste scores among all the products were insignificant ($P > 0.05$). This may be as a result of the absence of any significant differences in the aftertaste characteristics of the products, or panelists' inability to clearly distinguish between the aftertaste characteristics of the products. Product **591** (control) was however the most preferred product (2.98) followed by **712** (2.94), **755** (2.94) and **722** (2.90) (Figure 4.18).

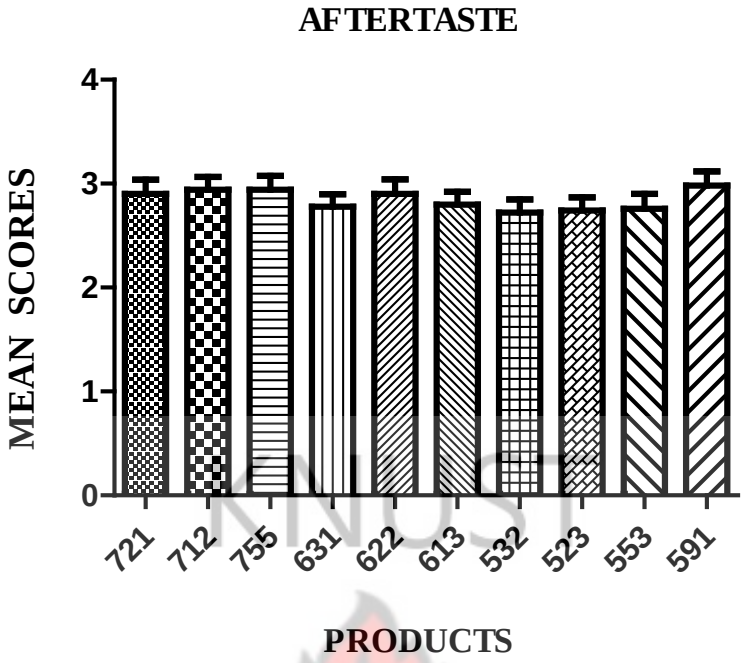


Figure 4.16 Panelist scores of acceptance test for aftertaste (Hedonic scale of 1 to 5; where 5 represents 'like very much' and 1 represents 'dislike very much'. 721 (70% Moringa + 20% Roselle + 10% Lemon grass); 712 (70% Moringa + 10% Roselle + 20% Lemon grass); 755 (70% Moringa + 15% Roselle + 15% Lemon grass); 631 (60% Moringa + 30% Roselle + 10% Lemon grass); 622 (60% Moringa + 20% Roselle + 20% Lemon grass); 613 (60% Moringa + 10% Roselle + 30% Lemon grass); 532 (50% Moringa + 30% Roselle + 20% Lemon grass); 523 (50% Moringa + 20% Roselle + 30% Lemon grass); 553 (55% Moringa + 15% Roselle + 30% Lemon grass); 591 (100% Moringa). Error bars indicate SEM at 5% probability; n=50**)**.

4.2.5 ASTRINGENCY

Astringency is generally recognized as a feeling of extreme dryness or puckeriness that is not confined to a particular region of the mouth or tongue, but is experienced invariably as a diffuse stimulus (Haslam and Lilley 1988). Product **631** (3.72) was the most preferred in astringency followed by **532** (3.64), **553** (3.22), **523** (3.18) and **622** (3.22) in that order (Figure 4.19). From the trend, products with low proportions of Roselle were least preferable in astringency. For example, products containing 10% Roselle or below – **613** (2.94), **712 (**2.96) and the **591** (control) (2.32) – had the lowest scores in astringency. On the other hand,

products with high proportions of Roselle such as **631** (3.72), **532** (3.64) and **622** (3.22) had corresponding high scores for astringency. This implies that the highly astringent quality of Roselle (Dominguez-Lopez *et al.*, 2008) was appealing to the panelists. This finding agrees with that by Wismer *et* al. (2004) that astringency is an important and often appealing characteristic of brewed tea. Product **591** (the control) had the lowest score for astringency (2.32) which was significantly different ($P < 0.05$) from those of all the other products.

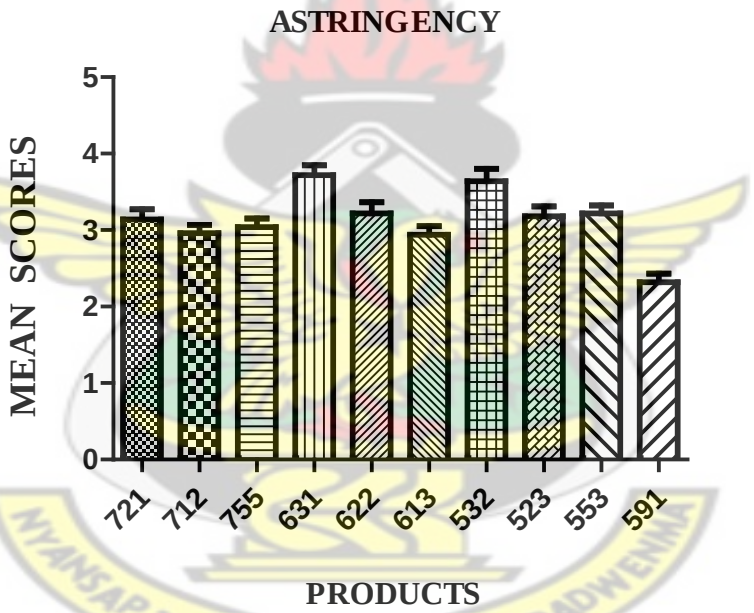


Figure 4.17 Panelist scores of acceptance test for astringency (Hedonic scale of 1 to 5; where 5 represents 'like very much' and 1 represents 'dislike very much'. 721 (70% Moringa + 20% Roselle + 10% Lemon grass); 712 (70% Moringa + 10% Roselle + 20% Lemon grass); 755 (70% Moringa + 15% Roselle + 15% Lemon grass); 631 (60% Moringa + 30% Roselle + 10% Lemon grass); 622 (60% Moringa + 20% Roselle + 20% Lemon grass); 613 (60% Moringa + 10% Roselle + 30% Lemon grass); 532 (50% Moringa + 30% Roselle + 20% Lemon grass); 523 (50% Moringa + 20% Roselle + 30% Lemon grass); 553 **(**55% Moringa **+** 15% Roselle + 30% Lemon grass); 591 (100% Moringa). Error bars indicate SEM at 5% probability; n=50**)**

4.2.6 OVERALL ACCEPTABILITY

Product **532** had the highest mean score in overall acceptability (4.08) (Figure 4.20). This was expected as it was the most preferred product in colour (3.90) and flavour (3.88), and the second most preferred product in aroma (3.94) and astringency (3.64). Conversely, **591** (control) was the least preferred product in overall acceptability (2.56). It scored the lowest preference for colour (2.68), aroma (2.66) and flavour (2.38). The mean score for overall acceptability of product **532** was significantly different ($P < 0.05$) from all the other samples with the exception of **613** (3.74). Likewise the mean score for overall acceptability of **591** (control) was significantly different ($P < 0.05$) from those of the other samples.

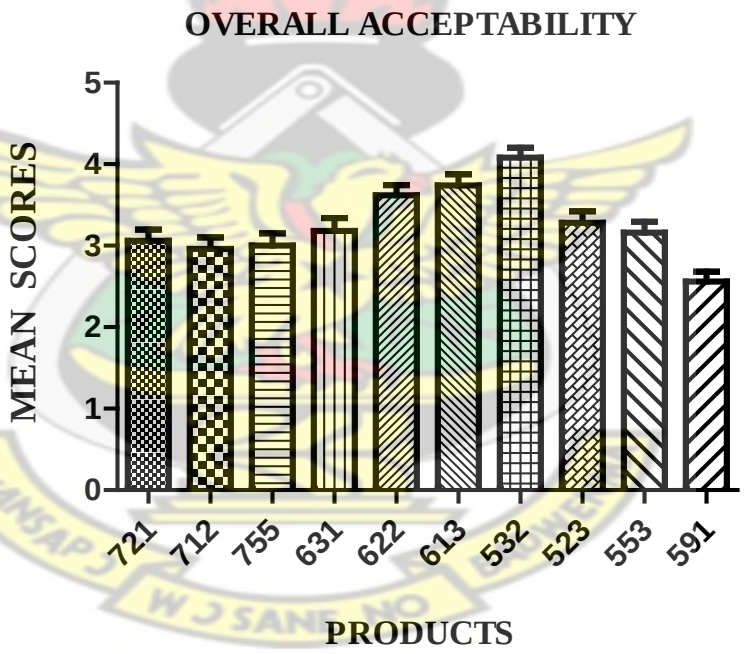


Figure 4.18 Panelist scores of acceptance test for overall acceptability (Hedonic scale of 1 to 5; where 5 represents 'like very much' and 1 represents 'dislike very much'. 721 (70% Moringa + 20% Roselle + 10% Lemon grass); 712 (70% Moringa + 10% Roselle + 20% Lemon grass); 755 (70% Moringa + 15% Roselle + 15% Lemon grass); 631 (60% Moringa + 30% Roselle + 10% Lemon grass); 622 (60% Moringa + 20% Roselle + 20% Lemon grass); 613 (60% Moringa + 10% Roselle + 30% Lemon grass); 532 (50% Moringa + 30% Roselle + 20% Lemon grass); 523 (50% Moringa + 20% Roselle + 30% Lemon grass); 553 (55% Moringa + 15% Roselle + 30% Lemon grass); 591 (100% Moringa). Error bars indicate SEM at 5% probability; n=50**)**

4.3 DESCRIPTIVE TESTS

During the training of the panelists, a total of 17 descriptors were generated, defined, referenced and scored by the panelists. These were grouped into 6 appearance, 3 aroma, 1 flavor, 5 taste and 2 mouthfeel descriptors.

4.3.1 APPEARANCE DESCRIPTORS

The appearance descriptors generated by the trained panel included four colours – Greenness, Yellowness, Redness and Brownness. Two additional attributes were Turbidity and Sparkling. Definitions and references were provided for all the attributes (Table 4.1).

Infusions from **591 (control)** were predominantly yellowish in colour (11.93) while those from product **532** were predominantly reddish (12.56) (Figure 4.20). This finding agrees with research findings by Tetteh (2008) which showed that Moringa tea is mainly a golden yellow beverage, contrary to expectations of it being green. The reddish colour of infusions from **532** is most likely a consequence of the high Roselle content (30%) in the formulation. As confirmed by Dominiguez-Lopez *et al.* (2008), the calyx of Roselle produces infusions which are intensely reddish in colour. This characteristic of Roselle is due to its high water-soluble anthocyanin pigment content (Du and Francis 1973; Mazza and Miniati 2000). It is therefore likely that the anthocyanins in the calyces may have more readily dissolved in infusion thereby overshadowing green pigments such as chlorophyll contained in Lemon grass and Moringa. This explanation is supported by the relatively high water soluble extractive (12.38%) of Roselle as recorded in the chemical analysis (section 4.16). The results of the acceptance tests show that the reddish colour of infusions from **532** was more preferable to the yellowish colour of infusions from **591** (control).

Infusions from product **532** scored highest in turbidity (12.67). This implies that the infusions from **532** were less transparent than infusions from the **591** (control) and **613**. Since pure Roselle calyx infusions yield transparent infusions (Dominiguez-Lopez *et al.*, 2008), the high turbidity may be caused by Lemon grass and Moringa. The yellowish infusions of the **591** (control**)** scored highest for Sparkling (9.93) (Figure 4.21).

Table 4.1 Definitions and references of appearance descriptors for herb tea

Descriptor	Definition	Reference
Greenness	Intensity of green colour of herb tea	Unripe tomato fruit
Yellowness	Intensity of yellow colour of herb tea	Margarine
Redness	Intensity of red colour of herb tea	Ripe tomato fruit
Brownness	Intensity of brown colour of herb tea	Groundnut paste
Turbidity	Cloudiness of herb tea	Soymilk
Sparkling	Luminous character or bright appearance of herb tea	Oil

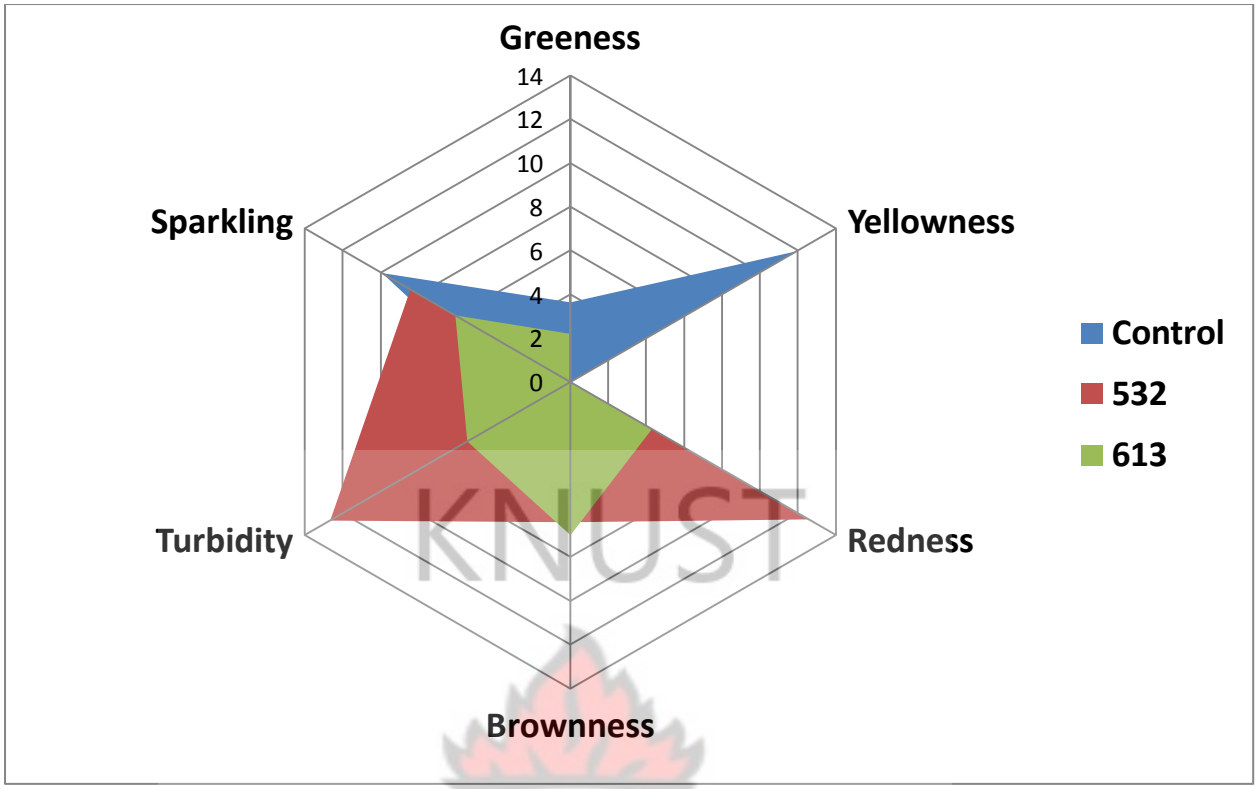


Figure 4.19 Quantitative scores for appearance descriptors of herb tea (Numerical scale (15-points) where '0' represents 'weak' and '15' represents 'strong'. 591 (100% Moringa); 532 (50% Moringa + 30% Roselle + 20% Lemon grass); 613 (60% Moringa + 10% Roselle + 30% Lemon grass). n=3**)**

4.3.2 AROMA AND FLAVOUR DESCRIPTORS

The trained panel generated, defined and referenced three descriptors to describe the aroma characteristics of the infusions: Citrus, Lemon grass and Herbal (Table 4.2).

Both **613** and **532** were rated high in Citrus aroma (11.74 and 11.30 respectively). The Citrus aroma identified by the trained panel is likely to be resulting from the Lemon grass constituent. As the name suggests, Lemon grass naturally possesses aroma characteristics similar to lemon, a citrus fruit. Predictably, the Citrus aroma was stronger in **613**, which contained 30% Lemon grass, than in **532** which contained only 20% Lemon grass. Product **591** (control) did not contain Lemon grass, consequently its infusions did not elicit significant Lemon grass aroma (0.59) or Citrus aroma (0.52).

Both **532** and **613** had high mean scores for Lemon grass aroma (11.07 and 10.07 respectively). This implies that the aroma of lemon grass was perceptible at 20% and 30% inclusion rate in the herb tea formulations. It also implies that even though Moringa was the dominant ingredient in both formulations (50% in **532** and 60% in **613**) it was unable to elicit strong aroma quality to overcome the Lemon grass aroma.

Product **532** scored high for Herbal aroma (11.41) compared to the score by **613** (6.81). Infusions from **591** (control) scored low in all the aroma attributes (≤ 1.89). The weak aroma quality of **591** (control) may have accounted for its low scores for aroma in the acceptance tests (section 4.2.2).

Even though none of the formulations contained ginger, the trained panel identified Ginger flavour. This may be explained on the basis of unpublished reports which describe Lemon grass as having 'a dominant lemon smell with a slight hint of ginger'. Alternatively, the observation may be due to ginger-like flavour perceptions arising from the combination of the three herbs. The Ginger flavour was however minimally perceived as shown by the low scores for all three products (≤ 1.30) (Figure 4.22).

Table 4.2 Definitions and references of aroma and flavour descriptors for herb tea

Descriptor	Definition	Reference
Herbal aroma	Aroma characteristics typical of dried eaves	Dried leaves
Citrus aroma	Aroma characteristics typical of citrus fruits	Orange fruit
Lemon grass aroma	Aroma characteristics typical of lemon grass leaves	Lemon grass leaf
Ginger flavour	Spicy flavour sensation typical of ginger root	Ginger root

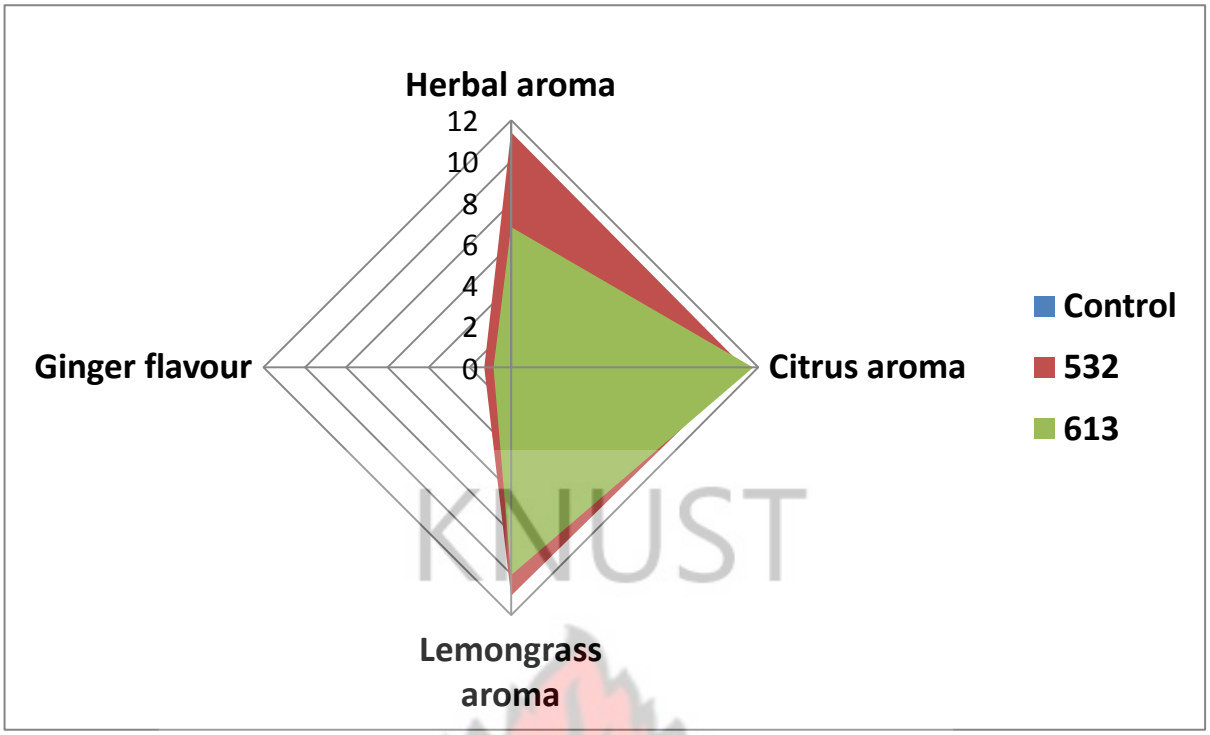


Figure 4.20 Quantitative scores for aroma and flavour descriptors of herb tea (Numerical scale (15-points) where '0' represents 'weak' and '15' represents 'strong'. 591 (100% Moringa); 532 (50% Moringa + 30% Roselle + 20% Lemon grass); 613 (60% Moringa + 10% Roselle + 30% Lemon grass). n=3**)**

4.3.3 TASTE DESCRIPTORS

Taste descriptors generated by the trained panel are shown in Table 4.3 below along with their definitions and references. With the exception of Sour taste, all the taste attributes were weak and therefore had low mean scores (≤ 1.52) (Figure 4.23). Infusions from product **532** had high scores for Sour taste (12.15) whereas those from product **613** had low scores (5.22). Infusions from **591** (control) had low scores for all the taste descriptors identified (≤ 0.19). Roselle has been known to produce sour and astringent infusions due to its high acid content (Ross, 2003). This is evidenced by the low pH of Roselle infusions (2.73) as shown by results of the chemical analyses (Figure 4.11). Product **532** may therefore have produced sourer infusions than product **613** due to the higher Roselle content in the former.

Table 4.3 Definitions and references of taste descriptors for herb tea

Descriptor	Definition	Reference
Sweet taste	Taste sensation typical of sucrose	Table sugar
Sour taste	Taste sensation typical of acidic fruits	Lemon juice
Bitter taste	Taste sensation typical of kola nut	Kola nut
Pungent aftertaste	Lingering spicy sensation after swallowing	Pepper
Bitter aftertaste	Lingering bitter taste after swallowing	Kola nut

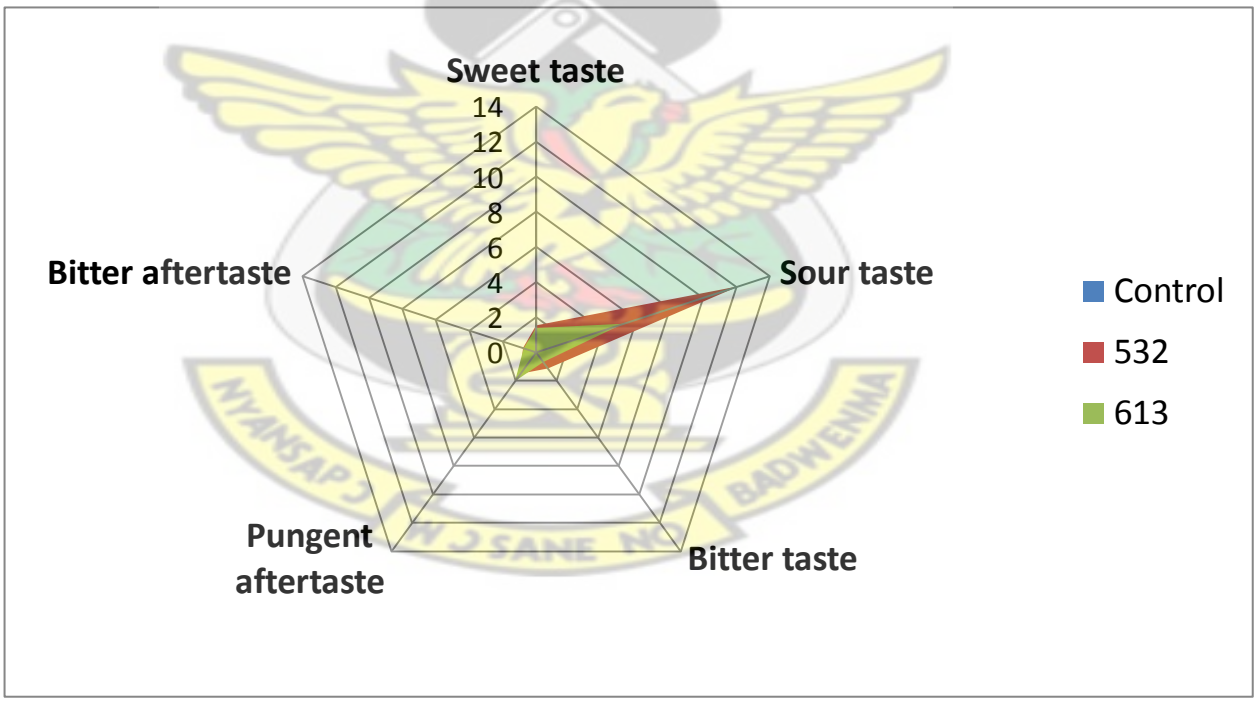


Figure 4.21 Quantitative scores for taste descriptors of herb tea (Numerical scale (15-points) where '0' represents 'weak' and '15' represents 'strong'. 591 (100% Moringa); 532 (50% Moringa + 30% Roselle + 20% Lemon grass); 613 (60% Moringa + 10% Roselle + 30% Lemon grass). n=3**)**

4.3.4 MOUTHFEEL DESCRIPTORS

Mouthfeel descriptors generated by the trained panel are shown in Table 4.4 below along with definitions and references. Product **532** was the most astringent (11.41) of the three products. It also had the highest mean score for Tooth-etching (8.67). Products **613** had comparatively higher scores for Astringency and Tooth-etching (3.48 and 1.59) than the **control** (0.19 and 0.00) (Figure 4.24). The high acid content of Roselle has been shown to cause astringency (Ross, 2003). It is therefore likely that panelists perceived the highest astringency in product **532** as a result of its high Roselle content. The same reason may account for the high scores for Tooth-etching in product **532.**

Table 4.4 Definitions and references of mouthfeel descriptors for herb tea

DESCRIPTOR	DEFINITION	REFERENCE
Astringency	Shriveling taste sensation on the tongue or pluckering of the oral tissue	Unripe banana
Tooth-etching	Sharp feeling on the tooth	Vinegar

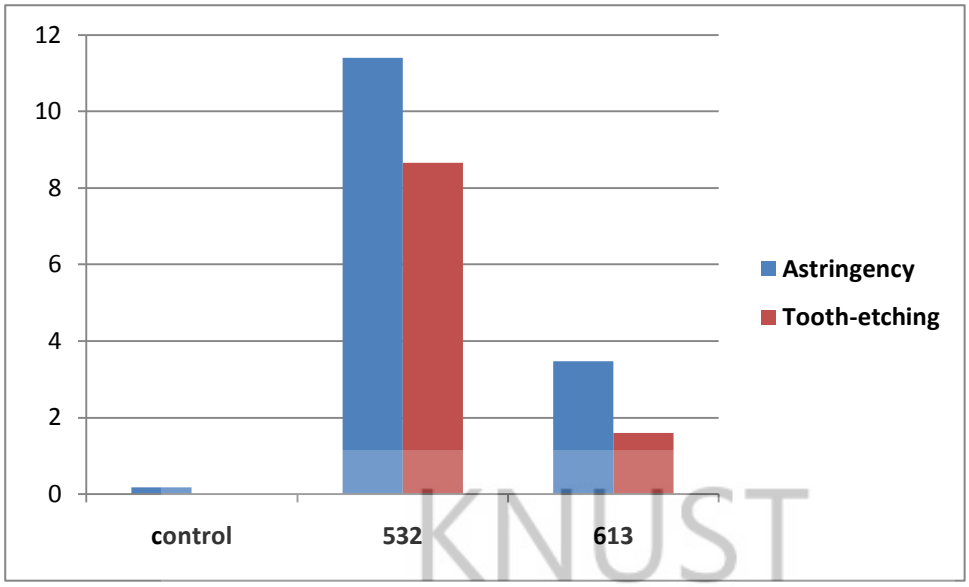
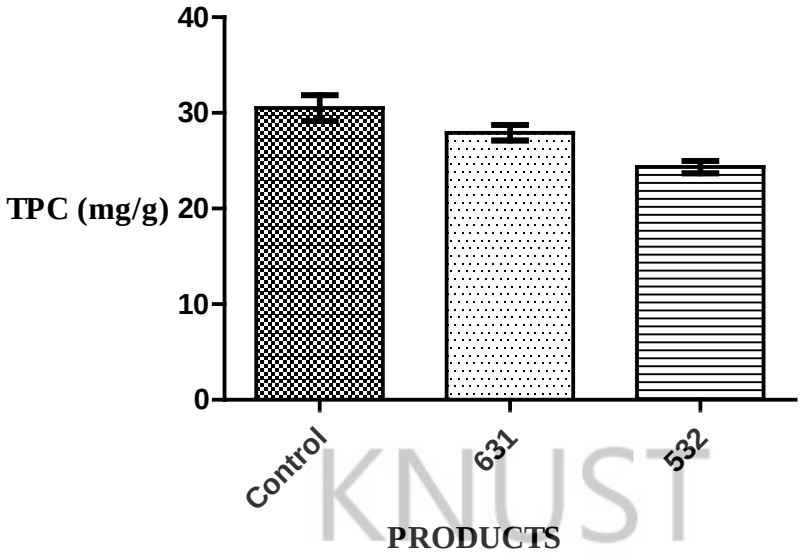


Figure 4.22 Quantitative scores for mouthfeel descriptors of herb tea (Numerical scale (15-points) where '0' represents 'weak' and '15' represents 'strong'. 591 (100% Moringa); 532 (50% Moringa + 30% Roselle + 20% Lemon grass); 613 (60% Moringa + 10% Roselle + 30% Lemon grass). n=3**)**

4.4 TOTAL POLYPHENOL CONTENT OF PRODUCTS

Total polyphenol tests were performed on infusions from three products used in the sensory evaluation tests. The results showed that the commercial herb tea (control) containing 100% Moringa recorded the highest polyphenol content (30.5 mg/g) while herb tea from products **631** and **532** recorded TPC values of 27.93 mg/g and 24.33 mg/g respectively (Fig 4.1.3). Between **631** and the **control** the difference was not significant ($P > 0.05$) while the difference was significant between **532** and the **control**. It can be inferred from the results that the TPC of the commercial Moringa herb tea was lower than that of the Moringa sample which was harvested fresh and dried for analysis. The difference could be due to poor storage conditions which may have led to the degradation of the phenolic compounds and/or the presence of impurities within the commercial product.



Figue 4.23 Total polyphenol content (TPC) of herb tea products (Error bars indicate SEM at 5% probability; n=3)

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

The results of the chemical analysis showed that Roselle calyx could potentially exert the strongest influence on the sensory character of the beverage compared with Lemon grass and Moringa leaf. This was evident from the relatively high water soluble extractive of Roselle (12.38%). Roselle also showed a relatively low pH (2.73) indicating its potential to impart sourness and astringency to herb tea. Lemon grass, on the other hand, recorded the highest light petroleum extractive (4.1%) which indicated its potential to impart aromatic quality to herb tea. The sample was also relatively high in crude fibre content (21.38%). Moringa leaf showed relatively high crude protein (26.59%) and crude ash content (8.57%) making it a suitable ingredient for malnutrition diets.

Herb tea brewed from product **532** (50% Moringa: 30% Roselle: 20% Lemon grass) was the most preferred in colour, flavour and overall acceptability while that from the **591** (control) (100% Moringa) was the least preferred in colour, aroma, flavour, astringency and overall acceptability. Blending Moringa, Roselle and Lemon grass produced a herb tea with more appealing characteristics than herb tea from only Moringa.

A total of 17 descriptors were generated, defined and referenced for herb tea. This included six appearance descriptors: Greenness, Yellowness, Redness, Brownness, Turbidity and Sparkling; three aroma descriptors: Herbal, Lemon grass and Citrus; one flavour descriptor: Ginger; five taste descriptors: Sweet taste, Sour taste, Bitter taste, Pungent aftertaste and Bitter aftertaste; and two mouthfeel descriptors: Astringency and Tooth-etching.

5.2 RECOMMENDATIONS

It is recommended that:

- The sensory appeal of infusions from blends of other herbs is compared with that of product 532;
- A full mineral and vitamin analysis of the infusions is performed;
- Measurements of the infusion dynamics are carried out; and
- A full microbiological analysis is carried out on the herb formulations.

REFERENCES

Abbey, L. and Timpo, G.M. (1999) Production and utilization of indigenous leafy vegetables: a proposal intervention model for Savannah zones of Ghana. Technical Note, Department of Horticulture, KNUST, Kumasi, Ghana.

Ali, B.H., Mousa, H.M., and El-Mougy, S. (2003). The effect of a water extract and anthocyanins of *Hibiscus sabdariffa* L. on paracetamol induced hepatoxicity in rats. Phythotherapy Research 17: 56 – 59.

Anwar, F., Latif, S., Ashraf, M. and Gilani, A.H. (2007) *Moringa oleifera*: A Food Plant with Multiple Medicinal Uses. *Phytotherapy Research* **21:** 17 – 25.

AOAC (1990) Official Methods of Analysis of the Association of Official Analytical Chemists (15th edition), Washington D.C., 992 – 995.

Appel, S.D. (2003) Red sorrel (*Hibiscus sabdariffa*) – the other 'cranberry'. *Plants and Garden News* **18**: 1 – 2.

Babalola, S.O. (2000) Chemical Composition of roselle (*Hibiscus sabdariffa* L.) calyx. Proceeding of the 24th Annual Conference of the Nigerian Institute of Food Science and Technology; 119 – 121.

Bajpai, M., Pande, A., Tewari, S.K. and Prakash, D. (2005) Phenolic contents and antioxidant activity of some food and medicinal plants. *International Journal of Food Sciences and Nutrition* **56** (4): 287 – 291.

Baratta, M.T., Dorman, H.J.D., Deans, S.G., Figueiredo, A.C., Barroso, J.G. and Ruberto, G. (1998) Antimicrobial and antioxidant properties of some commercial essential oils, *Flavour and Fragrance Journal* **13** (4): 235 – 244.

Barcenas, P., Perez Elortondo, F.J., Salmeron, J. and Albisu, M. (1999) Development of a preliminary sensory lexicon and standard references of ewes milk cheeses aided by multivariate statistical procedures. *Journal of Sensory Studies* **14**: 161 – 179.

BeMiller, J.N. and Whistler, R.L. (1999) Carbohydrates. In: Fennema, R.O., Karel, M., Sanderson, G.W.; Tannenbaum, S.R., Walstra, P., Witaker, J.R. (eds). Food Chemistry, Marcel Dekker Inc. New York, 219.

Bender, D.A. (2003) Benders' Dictionary of Nutrition and Food Technology, 7th Edition, CRC Press.

Bhattacharya, S.B., Das, A.K. and Banerji, N. (1982) Chemical investigations on the gum exudates from Sonja (*Moringa oleifera*). *Carbohydrates Research* **102**: 253 – 262.

Black, R.E. (2003) Zinc deficiency, infectious disease and mortality in the developing world. *Journal of Nutrition* **133**: 1484S – 9S.

Blench, R. (1997) Agriculture within the cultural system of the Tarok people of East Central Nigeria. (London: ODI) 137 – 139.

Booth, F.E.M. and Wickens, G.E. (1988) Non-timber uses of selected arid zone trees and shrubs in Africa. FAO Conservation Guide, Rome, 92 – 101.

Bricout, J. and Koziet, J. (1978) Characterization of synthetic substances in food flavours by isotropic analysis. In Flavour Symposium, Anals. 199 – 208.

Bridle, P. and Timberlake, C.F. (1997) Anthocyanins as natural food colour – selected aspects. *Food Chemistry* **58**: 103 – 9.

Buogo G. and Picchinenna D. (1937) Chemical characteristics of Roselle hemp. Journal of Applied Chemistry **27 (**4)**:** 577 – 582.

Byun, J.O. and Han, J.S. (2004) A study perception and actual status of utilization for green tea. *Korean Journal of Food Culture* **18:** 184–192.

Caceres, A., Cabrera, O., Morales, O., Mollinedo, P. and Mendia, P. (1991) Pharmacological properties of *Moringa oleifera* 1: Preliminary screening for antimicrobial activity. *Journal of Ethnopharmacolology* **33**: 213 – 216.

Caul, J.F. (1957) The profile method of flavor analysis. In Advances in Food Research, Vol 7 (E.M. Mrak and G.F. Stewart, eds.) Academic Press, New York, NY, 1 – 40.

Chambers, H.D. and Lee, J. (2007) A lexicon for flavor descriptive analysis of green tea. *Journal of Sensory Studies* **22**: 256 – 272.

Chen, C.C. (2003) *Hibiscus sabdariffa* extract inhibits development of atherosclerosis in cholesterol-fed rabbits. *Journal of Agricultural and Food Chemistry* **51**: 5472 – 7.

Chen, S.H., Huang, T.C., Ho, C.T. and Tsai, P.J. (1998) Extraction and study on the volatiles in roselle tea. *Journal of Agricultural Food Chemistry* **46**: 1101 – 1106.

Chisowa, E.H., Hall, D.R. and Farman D.I. (1998) Volatile Constituents of the Essential Oil of *Cymbopogon citrates* Stapf grown in Zambia. *Flavour and Fragrance Journal* **13**: 29 – 30.

Cho, H.Y., Chung, S.J., Kim, H.S. and Kim, K.O. (2005) Effect of sensory characteristics and non-sensory factors on consumer liking of various canned tea products. *Journal of Food Science* **79:** 532 – 538.

Choi, H.J., Lee,W.S., Hwang, S.J., Lee, I.J., Shin, D.H., Kim, H.Y. and Kim, K.U. (2000) Changes in chemical compositions of green tea (*Camellia sinensis* L.) under the different extraction conditions. *Korean Journal of Life Science* **10:** 202–209.

Chollet, S., and Valentin, D. (2001) Impact of training on beer flavor perception and description: are trained and untrained subjects really different? *Journal of Sensory Studies* **16:** 601 – 618.

Clydesdale, F.M., Main, J.H. and Francis, F.J. (1979) Roselle (*Hibiscus sabdariffa* L.) anthocyanins as colorant beverage and gelatin deserts. *Journal of Food Protection* **42**: 204 – 67.

De Cock, H.L., Kinnear, M. and Geel, L. (2005) Relating consumer preferences to sensory attributes of instant coffee. *Food Quality and Preference* **16** (3): 237 – 244.

Delgado-Vargas, F., Jiménez, A.R. and Paredes-López, O. (2000) Natural pigments: carotenoids, anthocyanins and betalains – characteristics, biosynthesis, processing and stability. *Critical Reviews in Food Science and Nutrition* **40**: 173 – 289.

Delgado-Vargas, F. and Parades-López, O. (2003). Chemicals and colorants as nutraceuticals. In: *Natural Colorants for Food and Nutraceutical Uses.*, pp. 257 – 305. CRC Press: Boca Raton, FL.

Design Expert (2007). State-Ease, Inc., Hennepin Square, Suite 480, 2021 E. Hennepin Ave., Minneapolis, MN 55413 – 2726.

D'Heureux-Calix, F. and Badrie, N. (2004) Consumer acceptance and physicochemical quality of processed red sorrel/roselle (*Hibiscus sabdariffa* L.) sauces from enzymatic extracted calyces. *Food Service Technology* **4**: 141 – 8.

Dominiguez-Lopez, A., Remondetto, G. E. and Salvador, N. (2008) Thermal kinetic degradation of anthocyanins in a roselle (*Hibiscus sabdariffa* L. cv. 'Criollo') infusion. *International Journal of Food Science and Technology* **43**: 322 – 325.

Downham, A. and Collins, P. (2000) Coloring our foods in the last millennium. *International Journal of Food Science and Technology*: **35**: 5 – 22.

Du, C.T. and Francis, F.J. (1973) Anthocyanins of roselle (*Hibiscus sabdariffa* L.) *Journal of Food Science* **38**: 810 – 812.

Dudai, N. (2001) Changes in essential oil during enzyme-assisted ensiling of Lemon grass (*Cymbopogon citratus*) (DC) Stapf and eucalyptus (*Eucalyptus citriodora* Hook). *Journal of Agricultural and Food Chemistry* **49** (5): 2262 – 6.

Dura´ n, L., Damasio, M. H., and Costell, E. (1989). Non-oral texture evaluation of mixed gels. Selection of parameters. In R. P. Sing, and A. G. Medina (Eds.), Food properties and computer aided engineering of food processing systems Dordrecht: Kluwer Academic. 321 – 326.

Ellis, H. (2002) Tea: Discovering, Exploring, Enjoying, Ryland Peters and Small, Inc., New York, NY. 38 – 47.

Esselen, W.B. and Sammy, G.M. (1973) Roselle: a natural red colorant for foods. *Food Product and Development* **7**: 80 – 82.

Euromonitor (2000) Functional Foods: World Survey, 2000. 68 – 76.

Ezeamuzle, I.C., Ambedederomo, A.W., Shode, F.O. and Ekwebelem, S.C., (1996) Antiinflammatory effects of *Moringa oleifera* root extract. *International Journal of Pharmacognosy* **34**: 207–212.

Faizi, S., Siddiqui, B.S., Saleem, R., Aftab, K., Shaheen, F. and Gilani, A.H. (1998) Hypotensive constituents from the pods of *Moringa oleifera*. *Planta Medica* **64** (3):225–228.

Faruq, M.O. (1994) TLC technique in the component characterization and quality determination of Bangladeshi Lemongrass oil (*Cymbopogon citratus*). *Bangladesh Journal of Science Industrial Research* **29** (2): 27 – 38.

Fennema, R.O. (1996) Water and Ice. In: Fennema, R.O., Karel, M., Sanderson, G.W., Tannenbaum, S.R., Walstra, P., Witaker, J.R. (eds.) Food Chemistry, Marcel Dekker Inc. New York. 52.

Figueirinha, A., Paranhos, A., Perez-Alonso, J.J., Santos-Buelga, C., Batista, M.A. (2008) *Cymbopogon citratus* leaves: Characterization of flavonoids by HPLC–PDA–ESI/MS/MS and an approach to their potential as a source of bioactive polyphenols. *Journal of Food Chemistry* **110** (3): 718 – 728.

Fuglie, L.G. (ed.) (2001) The Miracle Tree. *The Multiple Attributes of Moringa.* CTA, Wageningen, The Netherlands. 668 – 749.

Gains, N., and Thomson, D.M.H. (1990) Sensory profiling of canned lager beers using consumers in their own homes. *Food Quality and Preference* **2**: 39 – 47.

Ghasi, S., Nwobodo, E. and Ofili, J.O. (2000) Hypocholestrolaemic effects of crude extract of leaf of *Moringa oleifera* Lam in high fat diet fed to Wister rats. *Journal of Ethnopharmacology* **69**: 21–25.

Gilani, A.H., Aftab, K. and Shaheen, F. (1992) Antispasmodic activity of active principle from *Moringa oleifera.* In Natural Drugs and the Digestive Tract, Capasso F, Mascolo N (eds). EMSI: Rome, 60 – 63.

Gilani, A.H., Aftab, K. and Suria, A. (1994) Pharmacological studies on hypotensive and spasmodic activities of pure compounds from *Moringa oleifera. Phytotherapy Research* **8**: 87 – 91.

Gunasingh, C.B.G. and Nagarajan, S. (1981) Flavonoids of *Cymbopogon citratus. Indian Journal of Pharmaceutical Science* **43** (3): 115

.

Guy, C., Piggott, J.R., and Marie, S. (1989) Consumer profiling of Scotch whisky. *Food Quality and Preference* **1:** 69 – 73.

Haisman, D.R. and Clarke, M.W. (1975) The interfacial factor in the heat-induced conversion of chlorophyll to pheophytin in green leaves. *Journal of the Science of Food and Agriculture* **26**: 1111 – 26.

Hakim, I.A., Weisgerber, U.M., Harris, R.B., Balentine, D., van-Mierlo, C.A.J. and Paetau-Robinson, I. (2000) Preparation, composition and consumption patterns of tea-based beverages in Arizona. *Nutrition Research* **20** (12): 1715 – 1724.

Hamilton-Miller, J.M. (1995) Antimicrobial properties of tea (*Camellia sinensis.* L). *Antimicrobial Chemotherapy* **39** (11): 2375 – 2377.

Hanson, S.W. (1976) Cymbopogonol, a new triterpenoid from *Cymbopogon citratus*. *Phytochemistry* **15**: 1074 – 5.

Hara, Y., Luo, S., Wickremasinghe, R.L. and Yamanishi, T. (1995) Special issue on tea. Food Reviews International **11**: 371 – 542.

Haslam E. (1998) Practical Polyphenolics: From Structure to Molecular Recognition and Physiological Action. Cambridge University Press, Cambridge, UK. 89 – 93.

Haslam, E. and Lilley, T.H. (1988) Natural astringency in foodstuffs – A Molecular interpretation. *Critical Reviews in Food Science and Nutrition* **27**: 1 – 40.

Hirschorn, H.H. (1983) Botanical remedies of the former Dutch East Indies (Indonesia). Part 1: Eumycetes, Pteridophyta, Gmnospermae, Angilospermae (Monocotyledones only) *Journal of Ethnopharmacology* **7**: 123 – 56.

Hirunpanich, V., Utaipat, A., Morales, N.P., Bunyapraphatsara, N., Sato, H., Herunsalee, A. and Suthisisang, C. (2005) Antioxidant effects of aqueous extracts from dried calyx of *Hibiscus sabdariffa* L. (roselle) in vitro using low-density lipoprotein (LDL). *Biological and Pharmaceutical Bulletin* **28**: 481 – 4.

IFT. (1981) Sensory evaluation guide for testing food and beverage products. *Food Technology* **35** (11): 550 – 559.

Indovina R. and Capotummino G. (1938) Chemical analysis of karkade, the extract derived from *Hibiscus sabdariffa* L. cultivated in Sicily (Palermo) *Chemical Abstracts* **28**: 413 – 418.

International Tea Committee, Supplement to Annual Bulletin of Statistics, 1998. 103 – 146.

Jacomassi, E. and Piedade, L.H. (1994) Importance of medicinal plants and their use in the town of Goiore – PR. Revista da UNIMAR **16**: 335 – 53.

Jaganyi, D. and Mdletshe, S. (2000) Kinetics of tea infusion. Part 2: The effect of tea-bag material on the rate and temperature dependence of caffeine extraction from black Assam tea. *Food Chemistry* **70:** 163–165.

Jaganyi, D. and Price, R.D. (1999) Kinetics of tea infusion: The effect of the manufacturing process on the rate of extraction of caffeine. *Food Chemistry* **64**: 27–31.

Jensen, B. (2000) Guide to Body Chemistry and Nutrition. Keats Publishing, Illinois, U.S.A.. 55 – 80.

Johnsen, P.B., and Kelly, C.A. (1990) A technique for the quantitative sensory evaluation of farm-raised catfish. *Journal of Sensory Studies* **4:** 189 – 199.

Julkenen-Tito, M.R.K., Kirsi, M.J. and Rimpilaeinen, T.K. (1988) Methods of analysis and the aroma composition of some species of herbal teas. *Lebesm Wiss Technology* **21**(1); 36 – 40.

Jung, D.H. (2004) *Components and Effects of Tea* (In Korean), Hongikjae, Seoul, Korea. 28 – 43.

Kalogo, Y., Rosillon, F., Hammes F. and Verstraete W. (2000) Effect of a water extract of *Moringa oleifera* seeds on the hydrolytic microbial species diversity of a UASB reactor treating domestic waste water. *Letters in Applied Microbiology* **31**: 259 – 264.

Kar, A., Choudhary, B.K. and Bandyopadhyay, N.G. (2003) Comparative evaluation of hypoglycaemic activity of some Indian medicinal plants in alloxan diabetic rats. *Journal of Ethnopharmacology* **84** (1): 105–108.

Kasali, A.A., Oyedeji, A.O. and Ashilokun, A.O. (2001) Volatile leaf oil constituents of *Cymbopogon citratus* (DC) Stapf, *Flavour and Fragrance Journal* **16**(5): 377 – 378.

Kathiresan, K. (1965) Studies on tea from mangrove leaves. *Environmental Ecology* **13** (2**),** 321 – 323.

Keane, P. (1992) The flavor profile. In ` Manual on Descriptive Analysis Testing for Sensory Evaluation (R.C. Hootman, ed.) ASTM, Philadelphia, P.A. 2 – 15.

Kerharo, J. (1971) Senegal bisap (*Hibiscus sabdariffa*) or Guinea sorrel or red sorrel. Plant Med Phytother **5**: 277 – 281; from *Chemical Abstracts* 1972; **77**: 16568.

Khafaga E-SR and Koch, H. (1980) Stage of maturity and quality of roselle (*Hibiscus sabdariffa* L. var sabdariffa). 1. Organic acids. Angew Bot **54**: 287 – 293; from Chem Abstr 1980; **94**: 1711.

Khokhar, S. and Magnusdottir, S.G.M. (2002) Total phenol, catechin, and caffeine contents of teas commonly consumed in the United Kingdom. Journal of Agricultural Food Chemistry **50:** 565 – 570.

Kim, B.S., Yang, W.M. and Choi, J. (2002) Comparison of caffeine, free amino acid, vitamin C and catechins content of commercial green tea in Bosung, Sunchon, Kwangyang, Hadong. *Journal of Korean Tea Society* **8:** 55–62.

Kinugasa, H., Takeo, T. and Yano, N. (1997) Differences of flavor components found in green tea canned drinks made from tea leaves plucked on different matured stage. *Journal of Japanese Society for Food Science and Technology*. **44**(2): 112 – 118.

Kirk, R.S. and Sawyer, R. (1997) Pearson's Composition and Analysis of Foods (9th Ed) Longman Singapore Publishers; Singapore. 356 – 362.

Kumazawa, K. and Masuda, H. (2002) Identification of potent odorants in different green tea varieties using flavor dilution technique. *Journal of Agricultural Food Chemistry* **50**: 5660 – 5663.

Labbe, D., Rytz, A. and Hugi, A. (2003). Training is a critical step to obtain reliable product profiles in a real food industry context. *Food Quality and Preference* **15:** 341 – 348.

Larson, R.A. (1988) The antioxidants of higher plants. *Phytochemistry* **27**: 969–978.

Lawless, H.T., and Heymann, H. (1998) Sensory Evaluation of Food: Principles and Practices, Chapman and Hall, New York. 139 – 146.

Liang, Y., Lu, J., Zhang, L., Wu, S. and Wu, Y. (2003) Estimation of black tea quality by analysis of chemical composition and colour difference of tea infusions. *Food Chemistry* **80:** 283–290.

Lin, Y.C. (1975) The study of red pigments in Taiwan plants. *Proceedings of the National Science Council* Part 1 (Taiwan) **8**: 133 – 137.

Mahabir, D. and Gulliford, M.L. (1997) Use of medicinal plants for diabetes in Trinidad and Tobago. *Revista Panamericana de Salud Publica* **3**: 174 – 9.

Makkar, H.P.S., Bluemmel, M., Borowy, N.K. and Becker, K. (1993) Gravimetric determination of tannins and their correlations with chemical and protein precipitation methods. *Journal Science Food Agriculture* **61:** 161–165.

Makonnen, E., Hunde, A. and Damecha, G. (1997) Hypoglycaemic effect of *Moringa stenopetala* aqueous extract in rabbits. *Phytotherapy Research* **11**: 147 – 148.

Marongiu, B., Porcedda, S. and Piras, A. (2004) Antioxidant activity of supercritical extract of *Melissa officinalis subsp officinalis* and *Melissa officinalis* subsp *inodora*. *Phytotherapy Research* **18 (**10): 789 – 792

Mazza, G. (2000) Health aspects of natural colors. In: *Natural Food Colorants* (eds G.J. Lauro, F.J. Francis), Marcel Dekker: New York. 289 – 314.

Mazza, G. and Miniati, E. (2000) *Anthocyanin in Fruits, Vegetables and Grains.* CRC Press: Boca Raton, FL. 63 – 89.

McKay, D.L. and Blumberg, J.B. (2002) The role of tea in human health: an update. *Journal of the American College of Nutrition* **21**: 1 – 13.

Mien, K.H. and Mohamed, S. (2001) Flavonoid (Myricitin, Quercetin, Kaempferol, Luteolin and Apigenin) Content of Edible Tropical Plants. *Journal of Agricultural and Food Chemistry* **46**(6): 3106 – 12.

MINTEL. (2005). Category Review – Tea – August 2005. MINTEL Intl, Chicago, IL. 78 – 92.

Morton, J.F. (1974) Renewed interest in roselle (*Hibiscus sabdariffa* L.), the long-forgotten 'Florida cranberry'. *Proceedings of the Florida State Horticultural Society* **87**: 415 – 25.

Morton, J.F. (1991) The horseradish tree, *Moringa pterigosperma* (Monringaceae). A boon to arid lands. *Society for Economic Botany* **45**: 318 – 333.

Moskowitz, H. (1996) Descriptive analysis of perceptions. In Product testing and sensory evaluation of foods. Westport, CT: *Food Nutrition Press* 20 – 78.

Mounigan, P. and Badrie, N. (2006) Roselle/sorrel (*Hibiscus sabdariffa* L.) wines with varying calyx puree and total soluble solids: sensory acceptance, quantitative, descriptive and physicochemical analysis. *Blackwell Publishing Journal of Foodservice* (**17):** 102 – 110.

Munoz, A.M. and Civille, G.V. (1998) Universal, product and attribute specific scaling and the development of common lexicon in descriptive analysis. *Journal of Sensory Studies* **13**: 57 – 75.

Murakami, A., Kitazonz, Y., Jiwajinda, S., Koshimizu, K., Ohigashi, H. (1998). Niaziminin, a thiocarbamate from the leaves of *Moringa oleifera*, holds a strict structural requirement for inhibition of tumor promotor-induced Epstein-Barr virus activation. *Planta Medica* **64**: 319–323.

Nadkarni, A.K. (1976). Indian Materia Medica. Popular Prakashan: Bombay. *Chopra's indigenous drugs of India* **21:** 810 – 816.

Nambiar V., Bhadalkar K. and Daxini M. (2003) Drumstick leaves in the ICDS-SFP. *Indian Journal of Peadiatrics* **70**(5): 11-15.

Nambiar V. and Daniel M. (2005) Polyphenol content of three Indian green leafy vegetables. *Journal of Food Science and Technology* **42**(6): 312 – 315.

Nazlin, I. (1999) The role of visual cues in consumer perception and acceptance of a food product. *Journal of Nutrition and Food Science* Vol. 99, **5**: 224 – 230.

Ndabigengesere, A. and Narasiah, K.S. (1998) Quality of water treated by coagulation using *Moringa oleifera* seeds. *Water Research* **32**: 781 – 791.

Negrelle, R.R.B. and Gomes, E.C. (2007) *Cymbopogon citratus* (DC) Stapf: chemical composition and biological activities. Rev. Bras. Pl. Med., Botucatu **9:** 80 – 92.

Newton, K.A. (2007) Effect of spacing and harvest frequency on the growth, leaf quality and yield of *Moringa oleifera* as a leafy vegetable. MSc. Thesis, Faculty of Agriculture and Natural Resources, KNUST. 4 – 6.

Nnam, N.M. and Onyeke, N.G. (2003) Chemical composition of two varieties of sorrel (*Hibiscus sabdariffa* L.), calyces and the drinks made from them. *Plant Foods for Human Nutrition*. **58**: 1 – 7.

Obioma U.N. and Adikwu M.U. (1997) Investigation on some physiochemical antioxidant and toxicological properties of *Moringa oleifera* seed oil. Acta Pharmaceutica **47**: 287 – 290.

Olaniyi, A.A., Sofowora, E.A. and Oguntimenin, B.O. (1975) Phytochemical investigation of some Nigerian plants used against fevers. II *Cymbopogon citratus*. Planta Medica **28:**186 – 9.

Owusu, E. and Odamtten, G.T. (1999) Quality of Ghana herbal tea: microflora and control measures. *Journal of the Ghana Science Association* **1** (3): 84-99.

Pal, S.K., Mukherjee, P.K. and Saha, B.P. (1995) Studies on the antiulcer activity of *Moringa oleifera* leaf extract on gastric ulcer models in rats. *Phytotherapy Research* **9**: 463 – 465.

Park, G.S., Jeon, J.R. and Lee, S.J. (1999) The sensory characteristics of Korean green tea produced by Kujeungkupo's method. *Korean Journal Society of Food Science* **15**(5): 475 – 482.

Peigen, X. (1983) Recent developments on medicinal plants in China. *Journal of Ethnopharmacoloy* **7**: 95 – 109.

Piggott, J.R. (1991) Selection of terms for descriptive analysis. In Sensory Science Theory and Application in Food (H. Lawless and B. Klein, eds.) Marcel Dekker, New York, NY. 339 – 351.

Rainey, B.A. (1986) Importance of reference standards in training panelists. *Journal of Sensory Studies* **1**: 149 – 154.

Ramachandran, C., Peter, K.V. and Gopalakrishnan, P.K. (1980) Drumstic (*Moringa oleifera*): a multipurpose Indian vegetable. *Economic Botany* **34**: 276 – 283.

Reaubourg, G. and Monceaux, R.H. (1940) The chemical, botanical and pharmacological characteristics of the karkade (rosella) *Hibiscus sabdariffa* (gossypifolius). *Journal of Biological Chemistry* **1**: 292 – 305.

Rinzler, C.A. (2001) *The New Complete Book of Herbs, Spices, and Condiments,* Checkmark Books, New York, NY.

Roberfroid, M.B. (1999) Concepts in functional foods: the case of inulin and oligofructose. Journal of Nutrition **129** (7 Suppl): 1398 – 1401.

Roberts, A.K. and Vickers, Z.M. (1994) A comparison of trained and untrained judges, evaluation of sensory attribute intensities and liking of Cheddar cheeses. *Journal of Sensory Studies* **9:** 1 – 20.

Ross, I.A. (2003) *Hibiscus sabdariffa.* In: Medicinal Plants of the World. Vol 1, 2nd edn. Humana Press: New Jersey, 267 – 275.

Sandstead, H.H. (1982) Copper bioavailability and requirements. *American Journal of Clinical Nutrition*: Vol 35: 809 – 814.

Schmidt M., Schmitz H.J., Baumgart, A., Guedon, D., Netsch, M.I. and Kreuter, M.H. (2005) Toxicity of green tea extracts and their constituents in rat hepatocytes in primary culture. *Food Chemistry Toxicology* **43**: 307– 14.

Sharma, V., Gulati, A. and Ravindranath, S.D. (2005) Extractability of tea catechins as a function of manufacture procedure and temperature of infusion. *Food Chemistry* **93** (1): 141 – 148.

Shin, M.K. (1994) Science in green teas. *Korean Journal of Dietary Culture* **9:** 433–445.

Sloan, A.E. (2005) The center-store aisles. *Food Technology* **59**(10); 29 – 39.

Smith, J.C., Morris, E.R. and Ellis, R. (1983) Zinc: requirements, bioavailabilities and recommended allowances. *Clinical Biological Research* **129:** 147 – 169.

SRC (2002). Sorrel as a Nutraceutical – Health Benefits. Public Education Unit, the Scientific, Research Council of Jamaica, Kingston. 48 – 49.

Stampanoni, C.R. (1994) The use of standardized flavor languages and quantitative flavor profiling technique for flavored dairy products. *Journal of Sensory Studies* **9**: 383 – 400.

Stephens, J.M. (1994) *Roselle Hibiscus Sabdariffa L. Cooperative Extension Services.* Institute of Food and Agriculutural Sciences, University of Florida: Gainesville, FL. Fact Sheet HS – 659.

Stone, H., Sidel, J., Oliver, S., Woolsey, A. and Singleton, R.C. (1974) "Sensory evaluation by quantitative descriptive analysis", *Food Technology* **28** (11): 24 – 34.

Subramanian S.S. and Nair A.G.R. (1972) Flavonoids of four Malvaceous plants. *Phytochemistry* **11**: 1518 – 1519.

Takeda N. and Yasui Y. (1985) Identification of mutagenic substances in roselle color, elderberry color and safflower yellow. Agricultural Biological Chemistry **49**: 1851 – 1852.

Taylor, S. and McDowell, I. (1993) Tea: Types, production and trade. In: *Encyclopeadia of Food Sciences, Food Technology and Nutrition* (R. Macrae, R.K. Robinson and M.J. Sadler, eds.) Academic Press Inc., San Diego, CA. 4521 – 4527.

Tee, P.L.; Yusof, S.M.; Mohammed, S.; Umar, N.A. and Mohammed, M.N. (2002) Effect of roselle (*Hibiscus sabdariffa* L.) on serum lipids of Sprague Dawley rats. *Nutrition and Food Science* **32**: 351 – 6.

Tetteh, O.N.A. (2008) Effects of blanching and dehydration methods on the quality of Moringa leaf powder used as herbal green tea. MSc Thesis. Department of Biochemistry and Biotechnology, KNUST. 16 – 23.

The Wealth of India (A Dictionary of Indian Raw Materials and Industrial Products) (1962). Raw Materials, Vol. VI: L-M; Council for Scientific and Industrial Research: New Delhi, 425 – 429.

Togari, N., Kobayashi, A. and Aishima, T. (1995) Relating sensory properties of tea aroma to gas chromatographic data by chemometric calibration methods. *Food Research International* **28** (5): 485 – 493.

Tsai, P. McIntosh, J., Pearce, P., Camden, B. and Jordan, B.R. (2002) Anthocyanin and antioxidant capacity in roselle (*Hibiscus sabdariffa* L.) extract. *Food Research International* **35**: 351 – 6.

Tseng, T.H., Wang C.J., Kao E.S. and Chu C.Y. (1996) Hibiscus protocatechuic acid protects against oxidative damage induced by tert-butylhydroperoxide in rat primary hepatocytes *Medicinal Chemistry* **101**: 137 – 148.

Waldron, K.W., Parker, M.L. and Smith, A.C. (2003) Plant Cell Wall and Food Quality. A review, *Journal of Food Science and Technology* **2**: 109 – 110.

Walker, C.F., Kordas, K., Stoltzfus, R.J. and Black, R.E. (2005) Interactive effects of iron and zinc on biochemical and functional outcomes in supplementation trials. *American Journal of Clinical Nutrition* **82**(1): 5 – 12.

Wang, C.J., Wang, J.M. and Lin, W.L. (2000) Protective effect of *Hibiscus* anthocyanins against tert-butyl hydroperoxide-induced hepatic toxicity in rats. *Food Chemistry Toxicology* **38:** 411 – 416.

Wang, L.F., Kim, D.M. and Lee, C.Y. (2000) Effects of heat processing and storage on flavonols and sensory qualities of green tea beverage. *Journal of Agricultural Food Chemistry* **48**: 4227 – 4232.

Weerts, A.H., Martin, D.R., Lian, G. and Melrose, J.R. (2005) Modelling the hydration of foodstuffs. *Simulation, Modeling Practice* **13:** 119–128.

Wismer, W.V. and Goonewardene, L.A. (2004) Selection of an astringency reference standard for the evaluation of black tea. *Journal of Sensory Studies* **19:** 119 – 132.

Wolters, C.J., and Allchurch, E.M. (1994) Effect of training procedure on the performance of descriptive panels. *Food Quality Preference,* **5:** 203 – 214.

Wong, P.K., Yusof, S., Ghazali, H.M. and Che-Man, Y.B. (2002) Physico-chemical characteristics of roselle (*Hibiscus sabdariffa* L.). *Nutrition and Food Science* **32**: 68 – 73.

Xia, T., Shi, S. and Wan, X. (2006) Impact of ultrasonic-assisted extraction on the chemical and sensory quality of tea infusion. *Journal of Food Engineering* **74:** 557–560.

Yamanishi, T. (1977) Aroma of teas. *Koryo (Flavor)* **199**: 89 – 92.

Yau, N.J.N. and Haung, Y.J. (2000) The effect of membrane-processed water on sensory properties of oolong tea drinks. *Food Quality Preference* **11:** 331–339.

APPENDIX A
SENSORY EVALUATION FORM

Department of Food Science and Technology

You are provided with samples of herb teas. Please indicate your score of acceptance for the given attributes of the products using the five-point hedonic scale below.

SCALE

Score	Acceptance
5	'Like very much'
4	'Like slightly'
3	'Neither like nor dislike'
2	'Dislike slightly'
1	'Dislike very much'

EVALUATION FORM

SAMPLE	COLOUR	AROMA	FLAVOUR	AFTERTASTE	ASTRINGENCY	OVERALL ACCEPTABILITY
553						
721						
591						
523						
613						
712						
755						
631						
622						
532						

APPENDIX B

SUMMARY OF ANALYSIS OF VARIANCE

B1. ANOVA FOR CHEMICAL TESTS

I. MOISTURE CONTENT

P value	< 0.0001
P value summary	***
Are means signif. different? (P < 0.05)	Yes
Number of groups	3
F	23250
R squared	0.9999

ANOVA Table	SS	df	MS
Treatment (between columns)	9.816	2	4.908
Residual (within columns)	0.001267	6	0.0002111
Total	9.817	8	

Tukey's Multiple Comparison Test	Mean Diff.	q	Significant? P < 0.05?	Summary	95% CI of diff
Moringa vs Roselle	1.783	212.6	Yes	***	1.747 to 1.820
Moringa vs Lemon grass	2.480	295.6	Yes	***	2.444 to 2.516
Roselle vs Lemon grass	0.6967	83.05	Yes	***	0.6603 to 0.7331

II. CRUDE ASH CONTENT

P value	< 0.0001
P value summary	***
Are means signif. different? (P < 0.05)	Yes
Number of groups	3

F	8419				
R squared	0.9996				
ANOVA Table	SS	df	MS		
Treatment (between columns)	9.167	2	4.584		
Residual (within columns)	0.003267	6	0.0005444		
Total	9.170	8			
Tukey's Multiple Comparison Test	Mean Diff.	q	Significant? P < 0.05?	Summary	95% CI of diff
Moringa vs Roselle	-1.713	127.2	Yes	***	-1.772 to -1.655
Moringa vs Lemon grass	0.6867	50.97	Yes	***	0.6282 to 0.7451
Roselle vs Lemon grass	2.400	178.2	Yes	***	2.342 to 2.458

III. CALCIUM CONTENT

P value	< 0.0001				
P value summary	***				
Are means signif. different? (P < 0.05)	Yes				
Number of groups	3				
F	6198				
R squared	0.9995				
ANOVA Table	SS	df	MS		
Treatment (between columns)	104500	2	52230		
Residual (within columns)	50.56	6	8.427		
Total	104500	8			
Tukey's Multiple Comparison Test	Mean Diff.	q	Significant? P < 0.05?	Summary	95% CI of diff
Moringa vs Roselle	117.9	70.35	Yes	***	110.6 to 125.2
Moringa vs Lemon grass	263.4	157.2	Yes	***	256.1 to 270.7

Roselle vs Lemon grass	145.5	86.82	Yes	***	138.2 to 152.8

IV. IRON CONTENT

P value	< 0.0001
P value summary	***
Are means signif. different? (P < 0.05)	Yes
Number of groups	3
F	555700
R squared	1.000

ANOVA Table	SS	df	MS
Treatment (between columns)	291.0	2	145.5
Residual (within columns)	0.001571	6	0.0002618
Total	291.0	8	

Tukey's Multiple Comparison Test	Mean Diff.	q	Significant? P < 0.05?	Summary	95% CI of diff
Moringa vs Roselle	-11.33	1212	Yes	***	-11.37 to -11.29
Moringa vs Lemon grass	1.358	145.3	Yes	***	1.317 to 1.398
Roselle vs Lemon grass	12.68	1358	Yes	***	12.64 to 12.72

V. COPPER CONTENT

P value	< 0.0001
P value summary	***
Are means signif. different? (P < 0.05)	Yes
Number of groups	3
F	1188
R squared	0.9975

ANOVA Table	SS	df	MS
Treatment (between columns)	0.2064	2	0.1032

Residual (within columns)	0.0005212	6	0.00008686		
Total	0.2069	8			

Tukey's Multiple Comparison Test	Mean Diff.	q	Significant? P < 0.05?	Summary	95% CI of diff
Moringa vs Roselle	0.2493	46.34	Yes	***	0.2260 to 0.2727
Moringa vs Lemon grass	0.3625	67.37	Yes	***	0.3392 to 0.3858
Roselle vs Lemon grass	0.1132	21.03	Yes	***	0.08982 to 0.1365

VI. ZINC CONTENT

P value	< 0.0001
P value summary	***
Are means signif. different? (P < 0.05)	Yes
Number of groups	3
F	1831
R squared	0.9984

ANOVA Table	SS	df	MS
Treatment (between columns)	0.09157	2	0.04578
Residual (within columns)	0.0001500	6	0.00002500
Total	0.09172	8	

Tukey's Multiple Comparison Test	Mean Diff.	q	Significant? P < 0.05?	Summary	95% CI of diff
Moringa vs Roselle	0.06917	23.96	Yes	***	0.05664 to 0.08169
Moringa vs Lemon grass	0.2400	83.14	Yes	***	0.2275 to 0.2525
Roselle vs Lemon grass	0.1708	59.18	Yes	***	0.1583 to 0.1834

VII. CRUDE PROTEIN CONTENT

P value	< 0.0001
P value summary	***
Are means signif. different? (P < 0.05)	Yes

Number of groups	3				
F	606200				
R squared	1.000				
ANOVA Table	SS	df	MS		
Treatment (between columns)	700.5	2	350.3		
Residual (within columns)	0.003467	6	0.0005778		
Total	700.5	8			
Tukey's Multiple Comparison Test	Mean Diff.	q	Significant? P < 0.05?	Summary	95% CI of diff
Moringa vs Roselle	18.00	1297	Yes	***	17.94 to 18.06
Moringa vs Lemon grass	19.36	1395	Yes	***	19.30 to 19.42
Roselle vs Lemon grass	1.357	97.76	Yes	***	1.296 to 1.417

VIII. CRUDE FIBRE CONTENT

P value	< 0.0001				
P value summary	***				
Are means signif. different? (P < 0.05)	Yes				
Number of groups	3				
F	600.8				
R squared	0.9950				
ANOVA Table	SS	df	MS		
Treatment (between columns)	194.2	2	97.12		
Residual (within columns)	0.9699	6	0.1616		
Total	195.2	8			
Tukey's Multiple Comparison Test	Mean Diff.	q	Significant? P < 0.05?	Summary	95% CI of diff
Moringa vs Roselle	8.990	38.73	Yes	***	7.983 to 9.997
Moringa vs Lemon grass	-1.547	6.663	Yes	**	-2.554 to -0.5395
Roselle vs Lemon grass	-10.54	45.39	Yes	***	-11.54 to -9.529

IX. WATER SOLUBLE EXTRACTIVE

P value	< 0.0001
P value summary	***
Are means signif. different? (P < 0.05)	Yes
Number of groups	3
F	90720
R squared	1.000

ANOVA Table	SS	df	MS
Treatment (between columns)	104.8	2	52.41
Residual (within columns)	0.003467	6	0.0005778
Total	104.8	8	

Tukey's Multiple Comparison Test	Mean Diff.	q	Significant? P < 0.05?	Summary	95% CI of diff
Moringa vs Roselle	-4.943	356.2	Yes	***	-5.004 to -4.883
Moringa vs Lemon grass	3.367	242.6	Yes	***	3.306 to 3.427
Roselle vs Lemon grass	8.310	598.8	Yes	***	8.250 to 8.370

X. LIGHT PETROLEUM EXTRACTIVES

P value	< 0.0001
P value summary	***
Are means signif. different? (P < 0.05)	Yes
Number of groups	3
F	3210
R squared	0.9991

ANOVA Table	SS	df	MS
Treatment (between columns)	2.925	2	1.462
Residual (within columns)	0.002733	6	0.0004556
Total	2.928	8	

Tukey's Multiple Comparison Test	Mean Diff.	q	Significant? P < 0.05?	Summary	95% CI of diff
Moringa vs Roselle	0.7767	63.03	Yes	***	0.7232 to 0.8301

Moringa vs Lemon grass	-0.6167	50.04	Yes	***	-0.6701 to -0.5632
Roselle vs Lemon grass	-1.393	113.1	Yes	***	-1.447 to -1.340

XI. pH

P value	< 0.0001
P value summary	***
Are means signif. different? (P < 0.05)	Yes
Number of groups	3
F	261300
R squared	1.000

ANOVA Table	SS	df	MS
Treatment (between columns)	11.61	2	5.806
Residual (within columns)	0.0001333	6	0.00002222
Total	11.61	8	

Tukey's Multiple Comparison Test	Mean Diff.	q	Significant? P < 0.05?	Summary	95% CI of diff
Moringa vs Roselle	2.737	1006	Yes	***	2.725 to 2.748
Moringa vs Lemon grass	0.9333	342.9	Yes	***	0.9215 to 0.9451
Roselle vs Lemon grass	-1.803	662.6	Yes	***	-1.815 to -1.792

XII. TOTAL POLYPHENOLICS TEST ON HERB SAMPLES

P value	0.0001
P value summary	***
Are means signif. different? (P < 0.05)	Yes
Number of groups	3
F	54.19
R squared	0.9475

ANOVA Table	SS	df	MS

Treatment (between columns)	629.9	2	314.9		
Residual (within columns)	34.87	6	5.812		
Total	664.7	8			

Tukey's Multiple Comparison Test	Mean Diff.	q	Significant? P < 0.05?	Summary	95% CI of diff
Moringa vs Roselle	7.890	5.669	Yes	*	1.851 to 13.93
Moringa vs Lemon grass	20.32	14.60	Yes	***	14.28 to 26.36
Roselle vs Lemon grass	12.43	8.933	Yes	**	6.394 to 18.47

XIII. TOTAL POLYPHENOLICS TEST ON PRODUCTS

P value	0.0124
P value summary	*
Are means signif. different? (P < 0.05)	Yes
Number of groups	3
F	9.965
R squared	0.7686

ANOVA Table	SS	df	MS
Treatment (between columns)	57.58	2	28.79
Residual (within columns)	17.33	6	2.889
Total	74.91	8	

Tukey's Multiple Comparison Test	Mean Diff.	q	Significant? P < 0.05?	Summary	95% CI of diff
Control vs 631	2.567	2.616	No	ns	-1.691 to 6.825
Control vs 532	6.167	6.284	Yes	*	1.909 to 10.42
631 vs 532	3.600	3.669	No	ns	-0.6579 to 7.858

B2. ANOVA FOR ACCEPTANCE TESTS

I. COLOUR

P value	< 0.0001
P value summary	***
Are means signif. different? (P < 0.05)	Yes
Number of groups	10
F	13.01
R squared	0.1928

Bartlett's test for equal variances	
Bartlett's statistic (corrected)	37.16
P value	< 0.0001
P value summary	***
Do the variances differ signif. (P < 0.05)	Yes

ANOVA Table	SS	df	MS
Treatment (between columns)	78.12	9	8.680
Residual (within columns)	327.0	490	0.6674
Total	405.1	499	

Tukey's Multiple Comparison Test	Mean Diff.	q	Significant? P < 0.05?	Summary	95% CI of diff
721 vs 712	0.1600	1.385	No	ns	-0.3656 to 0.6856
721 vs 755	0.1000	0.8656	No	ns	-0.4256 to 0.6256
721 vs 631	-0.8800	7.617	Yes	***	-1.406 to -0.3544
721 vs 622	-0.2400	2.077	No	ns	-0.7656 to 0.2856
721 vs 613	-0.1800	1.558	No	ns	-0.7056 to 0.3456
721 vs 532	-0.9600	8.309	Yes	***	-1.486 to -0.4344
721 vs 523	-0.3600	3.116	No	ns	-0.8856 to 0.1656
721 vs 553	-0.04000	0.3462	No	ns	-0.5656 to 0.4856
721 vs 591	0.2600	2.250	No	ns	-0.2656 to 0.7856
712 vs 755	-0.06000	0.5193	No	ns	-0.5856 to 0.4656
712 vs 631	-1.040	9.002	Yes	***	-1.566 to -0.5144
712 vs 622	-0.4000	3.462	No	ns	-0.9256 to 0.1256
712 vs 613	-0.3400	2.943	No	ns	-0.8656 to 0.1856

712 vs 532	-1.120	9.694	Yes	***	-1.646 to -0.5944
712 vs 523	-0.5200	4.501	No	ns	-1.046 to 0.005552
712 vs 553	-0.2000	1.731	No	ns	-0.7256 to 0.3256
712 vs 591	0.1000	0.8656	No	ns	-0.4256 to 0.6256
755 vs 631	-0.9800	8.482	Yes	***	-1.506 to -0.4544
755 vs 622	-0.3400	2.943	No	ns	-0.8656 to 0.1856
755 vs 613	-0.2800	2.424	No	ns	-0.8056 to 0.2456
755 vs 532	-1.060	9.175	Yes	***	-1.586 to -0.5344
755 vs 523	-0.4600	3.982	No	ns	-0.9856 to 0.06555
755 vs 553	-0.1400	1.212	No	ns	-0.6656 to 0.3856
755 vs 591	0.1600	1.385	No	ns	-0.3656 to 0.6856
631 vs 622	0.6400	5.540	Yes	**	0.1144 to 1.166
631 vs 613	0.7000	6.059	Yes	**	0.1744 to 1.226
631 vs 532	-0.08000	0.6924	No	ns	-0.6056 to 0.4456
631 vs 523	0.5200	4.501	No	ns	-0.005552 to 1.046
631 vs 553	0.8400	7.271	Yes	***	0.3144 to 1.366
631 vs 591	1.140	9.867	Yes	***	0.6144 to 1.666
622 vs 613	0.06000	0.5193	No	ns	-0.4656 to 0.5856
622 vs 532	-0.7200	6.232	Yes	***	-1.246 to -0.1944
622 vs 523	-0.1200	1.039	No	ns	-0.6456 to 0.4056
622 vs 553	0.2000	1.731	No	ns	-0.3256 to 0.7256
622 vs 591	0.5000	4.328	No	ns	-0.02555 to 1.026
613 vs 532	-0.7800	6.751	Yes	***	-1.306 to -0.2544
613 vs 523	-0.1800	1.558	No	ns	-0.7056 to 0.3456
613 vs 553	0.1400	1.212	No	ns	-0.3856 to 0.6656
613 vs 591	0.4400	3.808	No	ns	-0.08555 to 0.9656
532 vs 523	0.6000	5.193	Yes	*	0.07445 to 1.126
532 vs 553	0.9200	7.963	Yes	***	0.3944 to 1.446
532 vs 591	1.220	10.56	Yes	***	0.6944 to 1.746
523 vs 553	0.3200	2.770	No	ns	-0.2056 to 0.8456
523 vs 591	0.6200	5.366	Yes	**	0.09445 to 1.146
553 vs 591	0.3000	2.597	No	ns	-0.2256 to 0.8256

II. AROMA

P value	< 0.0001
P value summary	***
Are means signif. different? (P < 0.05)	Yes
Number of groups	10
F	20.70
R squared	0.2755

Bartlett's test for equal variances	
Bartlett's statistic (corrected)	3.508
P value	0.9407
P value summary	ns
Do the variances differ signif. (P < 0.05)	No

ANOVA Table	SS	df	MS
Treatment (between columns)	139.4	9	15.49
Residual (within columns)	366.7	490	0.7484
Total	506.2	499	

Tukey's Multiple Comparison Test	Mean Diff.	q	Significant? P < 0.05?	Summary	95% CI of diff
721 vs 712	-0.02000	0.1635	No	ns	-0.5765 to 0.5365
721 vs 755	0.02000	0.1635	No	ns	-0.5365 to 0.5765
721 vs 631	-0.1800	1.471	No	ns	-0.7365 to 0.3765
721 vs 622	-0.8200	6.702	Yes	***	-1.377 to -0.2635
721 vs 613	-1.060	8.664	Yes	***	-1.617 to -0.5035
721 vs 532	-1.240	10.14	Yes	***	-1.797 to -0.6835
721 vs 523	-1.260	10.30	Yes	***	-1.817 to -0.7035
721 vs 553	-0.8400	6.866	Yes	***	-1.397 to -0.2835
721 vs 591	0.04000	0.3269	No	ns	-0.5165 to 0.5965
712 vs 755	0.04000	0.3269	No	ns	-0.5165 to 0.5965
712 vs 631	-0.1600	1.308	No	ns	-0.7165 to 0.3965
712 vs 622	-0.8000	6.539	Yes	***	-1.357 to -0.2435
712 vs 613	-1.040	8.501	Yes	***	-1.597 to -0.4835
712 vs 532	-1.220	9.972	Yes	***	-1.777 to -0.6635
712 vs 523	-1.240	10.14	Yes	***	-1.797 to -0.6835

712 vs 553	-0.8200	6.702	Yes	***	-1.377 to -0.2635
712 vs 591	0.06000	0.4904	No	ns	-0.4965 to 0.6165
755 vs 631	-0.2000	1.635	No	ns	-0.7565 to 0.3565
755 vs 622	-0.8400	6.866	Yes	***	-1.397 to -0.2835
755 vs 613	-1.080	8.828	Yes	***	-1.637 to -0.5235
755 vs 532	-1.260	10.30	Yes	***	-1.817 to -0.7035
755 vs 523	-1.280	10.46	Yes	***	-1.837 to -0.7235
755 vs 553	-0.8600	7.029	Yes	***	-1.417 to -0.3035
755 vs 591	0.02000	0.1635	No	ns	-0.5365 to 0.5765
631 vs 622	-0.6400	5.231	Yes	*	-1.197 to -0.08346
631 vs 613	-0.8800	7.193	Yes	***	-1.437 to -0.3235
631 vs 532	-1.060	8.664	Yes	***	-1.617 to -0.5035
631 vs 523	-1.080	8.828	Yes	***	-1.637 to -0.5235
631 vs 553	-0.6600	5.395	Yes	**	-1.217 to -0.1035
631 vs 591	0.2200	1.798	No	ns	-0.3365 to 0.7765
622 vs 613	-0.2400	1.962	No	ns	-0.7965 to 0.3165
622 vs 532	-0.4200	3.433	No	ns	-0.9765 to 0.1365
622 vs 523	-0.4400	3.596	No	ns	-0.9965 to 0.1165
622 vs 553	-0.02000	0.1635	No	ns	-0.5765 to 0.5365
622 vs 591	0.8600	7.029	Yes	***	0.3035 to 1.417
613 vs 532	-0.1800	1.471	No	ns	-0.7365 to 0.3765
613 vs 523	-0.2000	1.635	No	ns	-0.7565 to 0.3565
613 vs 553	0.2200	1.798	No	ns	-0.3365 to 0.7765
613 vs 591	1.100	8.991	Yes	***	0.5435 to 1.657
532 vs 523	-0.02000	0.1635	No	ns	-0.5765 to 0.5365
532 vs 553	0.4000	3.269	No	ns	-0.1565 to 0.9565
532 vs 591	1.280	10.46	Yes	***	0.7235 to 1.837
523 vs 553	0.4200	3.433	No	ns	-0.1365 to 0.9765
523 vs 591	1.300	10.63	Yes	***	0.7435 to 1.857
553 vs 591	0.8800	7.193	Yes	***	0.3235 to 1.437

III. FLAVOUR

P value	< 0.0001
P value summary	***
Are means signif. different? (P < 0.05)	Yes
Number of groups	10
F	21.89
R squared	0.2867

Bartlett's test for equal variances	
Bartlett's statistic (corrected)	16.51
P value	0.0571
P value summary	ns
Do the variances differ signif. (P < 0.05)	No

ANOVA Table	SS	df	MS
Treatment (between columns)	134.5	9	14.95
Residual (within columns)	334.6	490	0.6829
Total	469.1	499	

Tukey's Multiple Comparison Test	Mean Diff.	q	Significant? P < 0.05?	Summary	95% CI of diff
721 vs 712	0.0000	0.0000	No	ns	-0.5316 to 0.5316
721 vs 755	-0.04000	0.3423	No	ns	-0.5716 to 0.4916
721 vs 631	-0.4200	3.594	No	ns	-0.9516 to 0.1116
721 vs 622	-0.3400	2.909	No	ns	-0.8716 to 0.1916
721 vs 613	-0.3000	2.567	No	ns	-0.8316 to 0.2316
721 vs 532	-1.500	12.84	Yes	***	-2.032 to -0.9684
721 vs 523	-1.220	10.44	Yes	***	-1.752 to -0.6884
721 vs 553	-0.8600	7.359	Yes	***	-1.392 to -0.3284
721 vs 591	0.02000	0.1711	No	ns	-0.5116 to 0.5516
712 vs 755	-0.04000	0.3423	No	ns	-0.5716 to 0.4916
712 vs 631	-0.4200	3.594	No	ns	-0.9516 to 0.1116
712 vs 622	-0.3400	2.909	No	ns	-0.8716 to 0.1916
712 vs 613	-0.3000	2.567	No	ns	-0.8316 to 0.2316

712 vs 532	-1.500	12.84	Yes	***	-2.032 to -0.9684
712 vs 523	-1.220	10.44	Yes	***	-1.752 to -0.6884
712 vs 553	-0.8600	7.359	Yes	***	-1.392 to -0.3284
712 vs 591	0.02000	0.1711	No	ns	-0.5116 to 0.5516
755 vs 631	-0.3800	3.252	No	ns	-0.9116 to 0.1516
755 vs 622	-0.3000	2.567	No	ns	-0.8316 to 0.2316
755 vs 613	-0.2600	2.225	No	ns	-0.7916 to 0.2716
755 vs 532	-1.460	12.49	Yes	***	-1.992 to -0.9284
755 vs 523	-1.180	10.10	Yes	***	-1.712 to -0.6484
755 vs 553	-0.8200	7.017	Yes	***	-1.352 to -0.2884
755 vs 591	0.06000	0.5134	No	ns	-0.4716 to 0.5916
631 vs 622	0.08000	0.6845	No	ns	-0.4516 to 0.6116
631 vs 613	0.1200	1.027	No	ns	-0.4116 to 0.6516
631 vs 532	-1.080	9.241	Yes	***	-1.612 to -0.5484
631 vs 523	-0.8000	6.845	Yes	***	-1.332 to -0.2684
631 vs 553	-0.4400	3.765	No	ns	-0.9716 to 0.09162
631 vs 591	0.4400	3.765	No	ns	-0.09162 to 0.9716
622 vs 613	0.04000	0.3423	No	ns	-0.4916 to 0.5716
622 vs 532	-1.160	9.926	Yes	***	-1.692 to -0.6284
622 vs 523	-0.8800	7.530	Yes	***	-1.412 to -0.3484
622 vs 553	-0.5200	4.449	No	ns	-1.052 to 0.01162
622 vs 591	0.3600	3.080	No	ns	-0.1716 to 0.8916
613 vs 532	-1.200	10.27	Yes	***	-1.732 to -0.6684
613 vs 523	-0.9200	7.872	Yes	***	-1.452 to -0.3884
613 vs 553	-0.5600	4.792	Yes	*	-1.092 to -0.02838
613 vs 591	0.3200	2.738	No	ns	-0.2116 to 0.8516
532 vs 523	0.2800	2.396	No	ns	-0.2516 to 0.8116
532 vs 553	0.6400	5.476	Yes	**	0.1084 to 1.172
532 vs 591	1.520	13.01	Yes	***	0.9884 to 2.052
523 vs 553	0.3600	3.080	No	ns	-0.1716 to 0.8916
523 vs 591	1.240	10.61	Yes	***	0.7084 to 1.772
553 vs 591	0.8800	7.530	Yes	***	0.3484 to 1.412

IV. AFTERTASTE

P value	0.8545
P value summary	ns
Are means signif. different? (P < 0.05)	No
Number of groups	10
F	0.5280
R squared	0.009605

Bartlett's test for equal variances	
Bartlett's statistic (corrected)	3.497
P value	0.9413
P value summary	ns
Do the variances differ signif. (P < 0.05)	No

ANOVA Table	SS	df	MS
Treatment (between columns)	4.122	9	0.4580
Residual (within columns)	425.0	490	0.8674
Total	429.1	499	

Tukey's Multiple Comparison Test	Mean Diff.	q	Significant? P < 0.05?	Summary	95% CI of diff
721 vs 712	-0.04000	0.3037	No	ns	-0.6391 to 0.5591
721 vs 755	-0.04000	0.3037	No	ns	-0.6391 to 0.5591
721 vs 631	0.1200	0.9111	No	ns	-0.4791 to 0.7191
721 vs 622	0.0000	0.0000	No	ns	-0.5991 to 0.5991
721 vs 613	0.1000	0.7592	No	ns	-0.4991 to 0.6991
721 vs 532	0.1800	1.367	No	ns	-0.4191 to 0.7791
721 vs 523	0.1600	1.215	No	ns	-0.4391 to 0.7591
721 vs 553	0.1400	1.063	No	ns	-0.4591 to 0.7391
721 vs 591	-0.08000	0.6074	No	ns	-0.6791 to 0.5191
712 vs 755	0.0000	0.0000	No	ns	-0.5991 to 0.5991
712 vs 631	0.1600	1.215	No	ns	-0.4391 to 0.7591
712 vs 622	0.04000	0.3037	No	ns	-0.5591 to 0.6391
712 vs 613	0.1400	1.063	No	ns	-0.4591 to 0.7391

712 vs 532	0.2200	1.670	No	ns	-0.3791 to 0.8191
712 vs 523	0.2000	1.518	No	ns	-0.3991 to 0.7991
712 vs 553	0.1800	1.367	No	ns	-0.4191 to 0.7791
712 vs 591	-0.04000	0.3037	No	ns	-0.6391 to 0.5591
755 vs 631	0.1600	1.215	No	ns	-0.4391 to 0.7591
755 vs 622	0.04000	0.3037	No	ns	-0.5591 to 0.6391
755 vs 613	0.1400	1.063	No	ns	-0.4591 to 0.7391
755 vs 532	0.2200	1.670	No	ns	-0.3791 to 0.8191
755 vs 523	0.2000	1.518	No	ns	-0.3991 to 0.7991
755 vs 553	0.1800	1.367	No	ns	-0.4191 to 0.7791
755 vs 591	-0.04000	0.3037	No	ns	-0.6391 to 0.5591
631 vs 622	-0.1200	0.9111	No	ns	-0.7191 to 0.4791
631 vs 613	-0.02000	0.1518	No	ns	-0.6191 to 0.5791
631 vs 532	0.06000	0.4555	No	ns	-0.5391 to 0.6591
631 vs 523	0.04000	0.3037	No	ns	-0.5591 to 0.6391
631 vs 553	0.02000	0.1518	No	ns	-0.5791 to 0.6191
631 vs 591	-0.2000	1.518	No	ns	-0.7991 to 0.3991
622 vs 613	0.1000	0.7592	No	ns	-0.4991 to 0.6991
622 vs 532	0.1800	1.367	No	ns	-0.4191 to 0.7791
622 vs 523	0.1600	1.215	No	ns	-0.4391 to 0.7591
622 vs 553	0.1400	1.063	No	ns	-0.4591 to 0.7391
622 vs 591	-0.08000	0.6074	No	ns	-0.6791 to 0.5191
613 vs 532	0.08000	0.6074	No	ns	-0.5191 to 0.6791
613 vs 523	0.06000	0.4555	No	ns	-0.5391 to 0.6591
613 vs 553	0.04000	0.3037	No	ns	-0.5591 to 0.6391
613 vs 591	-0.1800	1.367	No	ns	-0.7791 to 0.4191
532 vs 523	-0.02000	0.1518	No	ns	-0.6191 to 0.5791
532 vs 553	-0.04000	0.3037	No	ns	-0.6391 to 0.5591
532 vs 591	-0.2600	1.974	No	ns	-0.8591 to 0.3391
523 vs 553	-0.02000	0.1518	No	ns	-0.6191 to 0.5791
523 vs 591	-0.2400	1.822	No	ns	-0.8391 to 0.3591
553 vs 591	-0.2200	1.670	No	ns	-0.8191 to 0.3791

V. ASTRINGENCY

P value	< 0.0001
P value summary	***
Are means signif. different? (P < 0.05)	Yes
Number of groups	10
F	9.617
R squared	0.1501

Bartlett's test for equal variances	
Bartlett's statistic (corrected)	18.47
P value	0.0301
P value summary	*
Do the variances differ signif. (P < 0.05)	Yes

ANOVA Table	SS	df	MS
Treatment (between columns)	67.78	9	7.531
Residual (within columns)	383.7	490	0.7831
Total	451.5	499	

Tukey's Multiple Comparison Test	Mean Diff.	q	Significant? P < 0.05?	Summary	95% CI of diff
721 vs 712	0.1800	1.438	No	ns	-0.3893 to 0.7493
721 vs 755	0.1000	0.7991	No	ns	-0.4693 to 0.6693
721 vs 631	-0.5800	4.635	Yes	*	-1.149 to -0.01072
721 vs 622	-0.08000	0.6393	No	ns	-0.6493 to 0.4893
721 vs 613	0.2000	1.598	No	ns	-0.3693 to 0.7693
721 vs 532	-0.5000	3.995	No	ns	-1.069 to 0.06928
721 vs 523	-0.04000	0.3196	No	ns	-0.6093 to 0.5293
721 vs 553	-0.08000	0.6393	No	ns	-0.6493 to 0.4893
721 vs 591	0.8200	6.552	Yes	***	0.2507 to 1.389
712 vs 755	-0.08000	0.6393	No	ns	-0.6493 to 0.4893
712 vs 631	-0.7600	6.073	Yes	**	-1.329 to -0.1907
712 vs 622	-0.2600	2.078	No	ns	-0.8293 to 0.3093
712 vs 613	0.02000	0.1598	No	ns	-0.5493 to 0.5893

712 vs 532	-0.6800	5.434	Yes	**	-1.249 to -0.1107
712 vs 523	-0.2200	1.758	No	ns	-0.7893 to 0.3493
712 vs 553	-0.2600	2.078	No	ns	-0.8293 to 0.3093
712 vs 591	0.6400	5.114	Yes	*	0.07072 to 1.209
755 vs 631	-0.6800	5.434	Yes	**	-1.249 to -0.1107
755 vs 622	-0.1800	1.438	No	ns	-0.7493 to 0.3893
755 vs 613	0.1000	0.7991	No	ns	-0.4693 to 0.6693
755 vs 532	-0.6000	4.794	Yes	*	-1.169 to -0.03072
755 vs 523	-0.1400	1.119	No	ns	-0.7093 to 0.4293
755 vs 553	-0.1800	1.438	No	ns	-0.7493 to 0.3893
755 vs 591	0.7200	5.753	Yes	**	0.1507 to 1.289
631 vs 622	0.5000	3.995	No	ns	-0.06928 to 1.069
631 vs 613	0.7800	6.233	Yes	***	0.2107 to 1.349
631 vs 532	0.08000	0.6393	No	ns	-0.4893 to 0.6493
631 vs 523	0.5400	4.315	No	ns	-0.02928 to 1.109
631 vs 553	0.5000	3.995	No	ns	-0.06928 to 1.069
631 vs 591	1.400	11.19	Yes	***	0.8307 to 1.969
622 vs 613	0.2800	2.237	No	ns	-0.2893 to 0.8493
622 vs 532	-0.4200	3.356	No	ns	-0.9893 to 0.1493
622 vs 523	0.04000	0.3196	No	ns	-0.5293 to 0.6093
622 vs 553	0.0000	0.0000	No	ns	-0.5693 to 0.5693
622 vs 591	0.9000	7.192	Yes	***	0.3307 to 1.469
613 vs 532	-0.7000	5.594	Yes	**	-1.269 to -0.1307
613 vs 523	-0.2400	1.918	No	ns	-0.8093 to 0.3293
613 vs 553	-0.2800	2.237	No	ns	-0.8493 to 0.2893
613 vs 591	0.6200	4.954	Yes	*	0.05072 to 1.189
532 vs 523	0.4600	3.676	No	ns	-0.1093 to 1.029
532 vs 553	0.4200	3.356	No	ns	-0.1493 to 0.9893
532 vs 591	1.320	10.55	Yes	***	0.7507 to 1.889
523 vs 553	-0.04000	0.3196	No	ns	-0.6093 to 0.5293
523 vs 591	0.8600	6.872	Yes	***	0.2907 to 1.429
553 vs 591	0.9000	7.192	Yes	***	0.3307 to 1.469

VI. OVERALL ACCEPTABILITY

P value	< 0.0001
P value summary	***
Are means signif. different? (P < 0.05)	Yes
Number of groups	10
F	10.18
R squared	0.1575

Bartlett's test for equal variances	
Bartlett's statistic (corrected)	7.844
P value	0.5499
P value summary	ns
Do the variances differ signif. (P < 0.05)	No

ANOVA Table	SS	df	MS
Treatment (between columns)	86.83	9	9.648
Residual (within columns)	464.3	490	0.9476
Total	551.2	499	

Tukey's Multiple Comparison Test	Mean Diff.	q	Significant? P < 0.05?	Summary	95% CI of diff
721 vs 712	0.1000	0.7264	No	ns	-0.5262 to 0.7262
721 vs 755	0.06000	0.4358	No	ns	-0.5662 to 0.6862
721 vs 631	-0.1200	0.8717	No	ns	-0.7462 to 0.5062
721 vs 622	-0.5600	4.068	No	ns	-1.186 to 0.06623
721 vs 613	-0.6800	4.940	Yes	*	-1.306 to -0.05377
721 vs 532	-1.020	7.409	Yes	***	-1.646 to -0.3938
721 vs 523	-0.2200	1.598	No	ns	-0.8462 to 0.4062
721 vs 553	-0.1000	0.7264	No	ns	-0.7262 to 0.5262
721 vs 591	0.5000	3.632	No	ns	-0.1262 to 1.126
712 vs 755	-0.04000	0.2906	No	ns	-0.6662 to 0.5862
712 vs 631	-0.2200	1.598	No	ns	-0.8462 to 0.4062
712 vs 622	-0.6600	4.794	Yes	*	-1.286 to -0.03377
712 vs 613	-0.7800	5.666	Yes	**	-1.406 to -0.1538
712 vs 532	-1.120	8.136	Yes	***	-1.746 to -0.4938
712 vs 523	-0.3200	2.324	No	ns	-0.9462 to 0.3062

712 vs 553	-0.2000	1.453	No	ns	-0.8262 to 0.4262
712 vs 591	0.4000	2.906	No	ns	-0.2262 to 1.026
755 vs 631	-0.1800	1.308	No	ns	-0.8062 to 0.4462
755 vs 622	-0.6200	4.504	No	ns	-1.246 to 0.006235
755 vs 613	-0.7400	5.375	Yes	**	-1.366 to -0.1138
755 vs 532	-1.080	7.845	Yes	***	-1.706 to -0.4538
755 vs 523	-0.2800	2.034	No	ns	-0.9062 to 0.3462
755 vs 553	-0.1600	1.162	No	ns	-0.7862 to 0.4662
755 vs 591	0.4400	3.196	No	ns	-0.1862 to 1.066
631 vs 622	-0.4400	3.196	No	ns	-1.066 to 0.1862
631 vs 613	-0.5600	4.068	No	ns	-1.186 to 0.06623
631 vs 532	-0.9000	6.538	Yes	***	-1.526 to -0.2738
631 vs 523	-0.1000	0.7264	No	ns	-0.7262 to 0.5262
631 vs 553	0.02000	0.1453	No	ns	-0.6062 to 0.6462
631 vs 591	0.6200	4.504	No	ns	-0.006234 to 1.246
622 vs 613	-0.1200	0.8717	No	ns	-0.7462 to 0.5062
622 vs 532	-0.4600	3.341	No	ns	-1.086 to 0.1662
622 vs 523	0.3400	2.470	No	ns	-0.2862 to 0.9662
622 vs 553	0.4600	3.341	No	ns	-0.1662 to 1.086
622 vs 591	1.060	7.700	Yes	***	0.4338 to 1.686
613 vs 532	-0.3400	2.470	No	ns	-0.9662 to 0.2862
613 vs 523	0.4600	3.341	No	ns	-0.1662 to 1.086
613 vs 553	0.5800	4.213	No	ns	-0.04623 to 1.206
613 vs 591	1.180	8.571	Yes	***	0.5538 to 1.806
532 vs 523	0.8000	5.811	Yes	**	0.1738 to 1.426
532 vs 553	0.9200	6.683	Yes	***	0.2938 to 1.546
532 vs 591	1.520	11.04	Yes	***	0.8938 to 2.146
523 vs 553	0.1200	0.8717	No	ns	-0.5062 to 0.7462
523 vs 591	0.7200	5.230	Yes	*	0.09377 to 1.346
553 vs 591	0.6000	4.358	No	ns	-0.02623 to 1.226

B3. ANOVA FOR DESCRIPTIVE TESTS

I. YELLOWNESS

P value	< 0.0001
P value summary	***
Are means signif. different? (P < 0.05)	Yes
Number of groups	3
F	6299
R squared	0.9938

Bartlett's test for equal variances	
Bartlett's statistic (corrected)	
P value	
P value summary	ns
Do the variances differ signif. (P < 0.05)	No

ANOVA Table	SS	df	MS
Treatment (between columns)	2560	2	1280
Residual (within columns)	15.85	78	0.2032
Total	2576	80	

Tukey's Multiple Comparison Test	Mean Diff.	q	Significant? P < 0.05?	Summary	95% CI of diff
Control vs 532	11.93	137.5	Yes	***	11.63 to 12.22
Control vs 613	11.93	137.5	Yes	***	11.63 to 12.22
532 vs 613	0.0000	0.0000	No	ns	-0.2938 to 0.2938

II. GREENNESS

P value	< 0.0001
P value summary	***
Are means signif. different? (P < 0.05)	Yes
Number of groups	3
F	183.3
R squared	0.8245

Bartlett's test for equal variances	
Bartlett's statistic (corrected)	
P value	
P value summary	ns
Do the variances differ signif. (P < 0.05)	No

ANOVA Table	SS	df	MS
Treatment (between columns)	180.3	2	90.16
Residual (within columns)	38.37	78	0.4919
Total	218.7	80	

Tukey's Multiple Comparison Test	Mean Diff.	q	Significant? P < 0.05?	Summary	95% CI of diff
control vs 532	3.630	26.89	Yes	***	3.173 to 4.087
control vs 613	1.444	10.70	Yes	***	0.9874 to 1.902
532 vs 613	-2.185	16.19	Yes	***	-2.642 to -1.728

III. REDNESS

P value	< 0.0001
P value summary	***
Are means signif. different? (P < 0.05)	Yes
Number of groups	3
F	2239
R squared	0.9829

Bartlett's test for equal variances	

Bartlett's statistic (corrected)	
P value	
P value summary	ns
Do the variances differ signif. (P < 0.05)	No

ANOVA Table	SS	df	MS
Treatment (between columns)	2199	2	1099
Residual (within columns)	38.30	78	0.4910
Total	2237	80	

Tukey's Multiple Comparison Test	Mean Diff.	q	Significant? P < 0.05?	Summary	95% CI of diff
Control vs 532	-12.56	93.11	Yes	***	-13.01 to -12.10
Control vs 613	-4.296	31.86	Yes	***	-4.753 to -3.840
532 vs 613	8.259	61.25	Yes	***	7.803 to 8.716

IV. BROWNNESS

P value	< 0.0001
P value summary	***
Are means signif. different? (P < 0.05)	Yes
Number of groups	3
F	507.6
R squared	0.9286

Bartlett's test for equal variances	
Bartlett's statistic (corrected)	
P value	
P value summary	ns
Do the variances differ signif. (P < 0.05)	No

ANOVA Table	SS	df	MS
Treatment (between columns)	813.7	2	406.8
Residual (within columns)	62.52	78	0.8015
Total	876.2	80	

Tukey's Multiple Comparison Test	Mean Diff.	q	Significant? P < 0.05?	Summary	95% CI of diff
Control vs 532	-6.407	37.19	Yes	***	-6.991 to -5.824
Control vs 613	-7.000	40.63	Yes	***	-7.583 to -6.417
532 vs 613	-0.5926	3.439	Yes	*	-1.176 to -0.009181

V. TURBIDITY

P value	< 0.0001
P value summary	***
Are means signif. different? (P < 0.05)	Yes
Number of groups	3
F	861.9
R squared	0.9567

Bartlett's test for equal variances	
Bartlett's statistic (corrected)	9.841
P value	0.0073
P value summary	**
Do the variances differ signif. (P < 0.05)	Yes

ANOVA Table	SS	df	MS
Treatment (between columns)	1518	2	758.8
Residual (within columns)	68.67	78	0.8803
Total	1586	80	

Tukey's Multiple Comparison Test	Mean Diff.	q	Significant? P < 0.05?	Summary	95% CI of diff
Control vs 532	-10.33	57.23	Yes	***	-10.94 to -9.722
Control vs 613	-3.111	17.23	Yes	***	-3.723 to -2.500
532 vs 613	7.222	40.00	Yes	***	6.611 to 7.834

VI. SPARKLING

P value	< 0.0001
P value summary	***
Are means signif. different? (P < 0.05)	Yes
Number of groups	3
F	79.21
R squared	0.6701

Bartlett's test for equal variances	
Bartlett's statistic (corrected)	1.095
P value	0.5784
P value summary	ns
Do the variances differ signif. (P < 0.05)	No

ANOVA Table	SS	df	MS
Treatment (between columns)	203.9	2	101.9
Residual (within columns)	100.4	78	1.287
Total	304.2	80	

Tukey's Multiple Comparison Test	Mean Diff.	q	Significant? P < 0.05?	Summary	95% CI of diff
Control vs 532	1.481	6.786	Yes	***	0.7423 to 2.221
Control vs 613	3.852	17.64	Yes	***	3.113 to 4.591
532 vs 613	2.370	10.86	Yes	***	1.631 to 3.110

VII. HERBAL AROMA

P value	< 0.0001
P value summary	***
Are means signif. different? (P < 0.05)	Yes
Number of groups	3
F	634.1
R squared	0.9421

Bartlett's test for equal variances

Bartlett's statistic (corrected)	0.3680
P value	0.8319
P value summary	ns
Do the variances differ signif. (P < 0.05)	No

ANOVA Table	SS	df	MS
Treatment (between columns)	1224	2	611.8
Residual (within columns)	75.26	78	0.9649
Total	1299	80	

Tukey's Multiple Comparison Test	Mean Diff.	q	Significant? P < 0.05?	Summary	95% CI of diff
Control vs 532	-9.519	50.35	Yes	***	-10.16 to -8.878
Control vs 613	-4.926	26.06	Yes	***	-5.566 to -4.286
532 vs 613	4.593	24.29	Yes	***	3.952 to 5.233

VIII. CITRUS AROMA

P value	< 0.0001
P value summary	***
Are means signif. different? (P < 0.05)	Yes
Number of groups	3
F	1189
R squared	0.9682

Bartlett's test for equal variances	
Bartlett's statistic (corrected)	7.997
P value	0.0183
P value summary	*
Do the variances differ signif. (P < 0.05)	Yes

ANOVA Table	SS	df	MS
Treatment (between columns)	2181	2	1090
Residual (within columns)	71.56	78	0.9174
Total	2252	80	

Tukey's Multiple Comparison Test	Mean Diff.	q	Significant? P < 0.05?	Summary	95% CI of diff
Control vs 532	-10.78	58.47	Yes	***	-11.40 to -10.15
Control vs 613	-11.22	60.88	Yes	***	-11.85 to -10.60
532 vs 613	-0.4444	2.411	No	ns	-1.069 to 0.1797

IX. LEMON GRASS AROMA

P value	< 0.0001
P value summary	***
Are means signif. different? (P < 0.05)	Yes
Number of groups	3
F	900.9
R squared	0.9585

Bartlett's test for equal variances	
Bartlett's statistic (corrected)	10.22
P value	0.0060
P value summary	**
Do the variances differ signif. (P < 0.05)	Yes

ANOVA Table	SS	df	MS
Treatment (between columns)	1807	2	903.4
Residual (within columns)	78.22	78	1.003
Total	1885	80	

Tukey's Multiple Comparison Test	Mean Diff.	q	Significant? P < 0.05?	Summary	95% CI of diff
Control vs 532	-10.48	54.39	Yes	***	-11.13 to -9.829
Control vs 613	-9.481	49.20	Yes	***	-10.13 to -8.829
532 vs 613	1.000	5.189	Yes	**	0.3474 1.653

X. GINGER FLAVOUR

P value	< 0.0001
P value summary	***
Are means signif. different? (P < 0.05)	Yes
Number of groups	3
F	23.10
R squared	0.3720

Bartlett's test for equal variances	
Bartlett's statistic (corrected)	29.14
P value	< 0.0001
P value summary	***
Do the variances differ signif. (P < 0.05)	Yes

ANOVA Table	SS	df	MS
Treatment (between columns)	20.67	2	10.33
Residual (within columns)	34.89	78	0.4473
Total	55.56	80	

Tukey's Multiple Comparison Test	Mean Diff.	q	Significant? P < 0.05?	Summary	95% CI of diff
Control vs 532	-1.222	9.496	Yes	***	-1.658 to -0.7864
Control vs 613	-0.7778	6.043	Yes	***	-1.214 to -0.3420
532 vs 613	0.4444	3.453	Yes	*	0.008617 to 0.8803

XI. SWEET TASTE

P value	< 0.0001
P value summary	***
Are means signif. different? (P < 0.05)	Yes
Number of groups	3
F	17.82
R squared	0.3136

Bartlett's test for equal variances					
Bartlett's statistic (corrected)	18.18				
P value	0.0001				
P value summary	***				
Do the variances differ signif. (P < 0.05)	Yes				

ANOVA Table	SS	df	MS
Treatment (between columns)	28.84	2	14.42
Residual (within columns)	63.11	78	0.8091
Total	91.95	80	

Tukey's Multiple Comparison Test	Mean Diff.	q	Significant? P < 0.05?	Summary	95% CI of diff
Control vs 532	-1.333	7.702	Yes	***	-1.920 to -0.7472
Control vs 613	-1.185	6.846	Yes	***	-1.771 to -0.5990
532 vs 613	0.1481	0.8558	No	ns	-0.4380 to 0.7343

XII. SOUR TASTE

P value	< 0.0001
P value summary	***
Are means signif. different? (P < 0.05)	Yes
Number of groups	3
F	1221
R squared	0.9690

Bartlett's test for equal variances			
Bartlett's statistic (corrected)			
P value			
P value summary	ns		
Do the variances differ signif. (P < 0.05)	No		

ANOVA Table	SS	df	MS

Treatment (between columns)	2005	2	1003		
Residual (within columns)	64.07	78	0.8215		
Total	2069	80			

Tukey's Multiple Comparison Test	Mean Diff.	q	Significant? P < 0.05?	Summary	95% CI of diff
Control vs 532	-12.15	69.65	Yes	***	-12.74 to -11.56
Control vs 613	-5.222	29.94	Yes	***	-5.813 to -4.632
532 vs 613	6.926	39.71	Yes	***	6.335 to 7.517

XIII. BITTER TASTE

P value	< 0.0001
P value summary	***
Are means signif. different? (P < 0.05)	Yes
Number of groups	3
F	13.18
R squared	0.2526
Bartlett's test for equal variances	
Bartlett's statistic (corrected)	15.95
P value	0.0003
P value summary	***
Do the variances differ signif. (P < 0.05)	Yes

ANOVA Table	SS	df	MS
Treatment (between columns)	12.54	2	6.272
Residual (within columns)	37.11	78	0.4758
Total	49.65	80	

Tukey's Multiple Comparison Test	Mean Diff.	q	Significant? P < 0.05?	Summary	95% CI of diff
Control vs 532	-0.9630	7.254	Yes	***	-1.412 to -0.5135
Control vs 613	-0.5185	3.906	Yes	*	-0.9680 to -0.06903
532 vs 613	0.4444	3.348	No	ns	-0.005048 to 0.8939

XIV. PUNGENT AFTERTASTE

P value	< 0.0001
P value summary	***
Are means signif. different? (P < 0.05)	Yes
Number of groups	3
F	70.03
R squared	0.6423

Bartlett's test for equal variances	
Bartlett's statistic (corrected)	
P value	
P value summary	ns
Do the variances differ signif. (P < 0.05)	No

ANOVA Table	SS	df	MS
Treatment (between columns)	60.52	2	30.26
Residual (within columns)	33.70	78	0.4321
Total	94.22	80	

Tukey's Multiple Comparison Test	Mean Diff.	q	Significant? P < 0.05?	Summary	95% CI of diff
Control vs 532	-1.519	12.00	Yes	***	-1.947 to -1.090
Control vs 613	-2.037	16.10	Yes	***	-2.465 to -1.609
532 vs 613	-0.5185	4.099	Yes	*	-0.9469 to -0.09016

XV. BITTER AFTERTASTE

P value	< 0.0001
P value summary	***
Are means signif. different? (P < 0.05)	Yes
Number of groups	3
F	39.62
R squared	0.5040

Bartlett's test for equal variances	
Bartlett's statistic (corrected)	24.42
P value	< 0.0001
P value summary	***
Do the variances differ signif. (P < 0.05)	Yes

ANOVA Table	SS	df	MS
Treatment (between columns)	28.22	2	14.11
Residual (within columns)	27.78	78	0.3561
Total	56.00	80	

Tukey's Multiple Comparison Test	Mean Diff.	q	Significant? P < 0.05?	Summary	95% CI of diff
Control vs 532	-1.444	12.58	Yes	***	-1.833 to -1.056
Control vs 613	-0.6667	5.805	Yes	***	-1.056 to -0.2778
532 vs 613	0.7778	6.772	Yes	***	0.3889 to 1.167

XVI. ASTRINGENCY

P value	< 0.0001
P value summary	***
Are means signif. different? (P < 0.05)	Yes
Number of groups	3
F	156.8
R squared	0.8008

Bartlett's test for equal variances					
Bartlett's statistic (corrected)	18.61				
P value	< 0.0001				
P value summary	***				
Do the variances differ signif. (P < 0.05)	Yes				

ANOVA Table	SS	df	MS
Treatment (between columns)	166.7	2	83.37
Residual (within columns)	41.48	78	0.5318
Total	208.2	80	

Tukey's Multiple Comparison Test	Mean Diff.	q	Significant? P < 0.05?	Summary	95% CI of diff
Control vs 532	-0.5926	4.222	Yes	*	-1.068 to -0.1174
Control vs 613	-3.296	23.49	Yes	***	-3.772 to -2.821
532 vs 613	-2.704	19.26	Yes	***	-3.179 to -2.228

XVII. TOOTH-ETCHING

P value	< 0.0001
P value summary	***
Are means signif. different? (P < 0.05)	Yes
Number of groups	3
F	1017
R squared	0.9631

Bartlett's test for equal variances			
Bartlett's statistic (corrected)			
P value			
P value summary	ns		
Do the variances differ signif. (P < 0.05)	No		

ANOVA Table	SS	df	MS

Treatment (between columns)	2061	2	1030		
Residual (within columns)	79.04	78	1.013		
Total	2140	80			

Tukey's Multiple Comparison Test	Mean Diff.	q	Significant? P < 0.05?	Summary	95% CI of diff
Control vs 532	-11.41	58.88	Yes	***	-12.06 to -10.75
Control vs 613	-1.593	8.221	Yes	***	-2.249 to -0.9366
532 vs 613	9.815	50.66	Yes	***	9.159 to 10.47