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TOPIC:

PHYTOCHEMICALS: THE HIDDEN GIFTS OF NATURE TO MANKIND

By

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An Inaugural Lecture Delivered at the University of Lagos
J. F. Ade. Ajayi Auditorium on Wednesday 24th July 2019

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DEDICATION

I dedicate this inaugural lecture to the Holy Trinity: Almighty God, Jesus Christ and the Holy Spirit. I also dedicate this lecture to all members of my family.

PROTOCOLS

The Vice-Chancellor,
Deputy Vice-Chancellor (Academics and Research),
Deputy Vice-Chancellor, (Management Services),
Deputy Vice-Chancellor, (Development Services),
Registrar,
Bursar,
The University Librarian,
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Other Principal Officers of the University
Distinguished Academic and Professional Colleagues,
Distinguished non-teaching Colleagues (Administrative and Technical),
Your Lordship (Spiritual and Temporal),
Your Royal Majesties and Highnesses,
Family & Friends,
Dear Students (Past and Present),
Distinguished Guests, Ladies and Gentlemen

Mr. Vice-Chancellor, Sir, I am so glad that the Almighty God made this day possible for me, to Him alone be all Glory! The first Inaugural Lecture in the department of Chemistry was delivered in 1968 by Prof Akisanya, titled "New Wine in Old skin". After 51 years, I am delivering the 8th Inaugural lecture in Chemistry in this great University titled **"Phytochemicals: The Hidden Gifts of Nature to Mankind"**. Mr. Vice-Chancellor, this Inaugural lecture, therefore, is the 2nd in the specialty of Natural Product Chemistry from our Department.

My teaching and research interest lie principally in Organic Chemistry. In this inaugural lecture, I will showcase my findings as a natural product researcher in the last two decades in the fields of Essential oil research, Phytochemistry and Organic

Synthesis. I have contributed to knowledge in these three areas of organic chemistry.

INTRODUCTION

Chemistry is important because as the cliché goes everything on earth is chemistry! Even our bodies are made of chemicals. Chemical reactions occur when you breathe, eat, or just sit there reading. All matter are made of chemicals, so the importance of chemistry is pervasive. Organic chemistry, on the other hand, plays an important part in our daily life because food, clothes, paper, ink, rubber, soap, perfumes, medicines etc. that are indispensable to us for a proper living are all organic based compounds.

Organic chemistry is a sub-discipline of chemistry that studies the structure, properties and reactions of organic compounds, which contain carbon in covalent bonding. The study of structure determines their chemical composition and formula. Study of properties includes physical and chemical properties, and evaluation of chemical reactivity to understand their behaviour. The study of organic reactions includes the chemical synthesis of natural products, drugs, and polymers, and the study of individual organic molecules in the laboratory via theoretical, pratical or experimental study.

Natural products chemistry is the study of natural products, which are organic compounds that are synthesised by living organisms. The science of organic chemistry has its origin in the study of natural products and has given rise to the fields of synthetic organic chemistry where scientists create organic compounds in the laboratory, and semi-synthetic organic chemistry where scientists modify existing natural products to improve or alter their activities. Natural products have high structural diversity and unique pharmacological or biological activities due to the natural selection and evolutionary processes that have shaped their utility over hundreds of thousands of years. In fact, the structural diversity of natural products far exceeds the capabilities of synthetic organic chemists within the laboratory. Thus, natural products have

been utilised in both traditional and modern medicine for treating diseases. Currently, natural products are often used as starting points for drug discovery followed by synthetic modifications to help reduce side effects and increase bioavailability. Natural products may be classified according to their biological function, biosynthetic pathway, or their source. The study of natural products offers an excellent strategy for identifying novel biological probes for a number of diseases. Historically, natural products have played an important role in the development of pharmaceutical drugs for a number of diseases including cancer, diabetes and infections.

Natural products, especially within the field of organic chemistry, are often defined as primary and secondary metabolites. Primary metabolites are components of basic metabolic pathways that are required for life. They are associated with essential cellular functions such as nutrient assimilation, energy production, and growth/development, they include the building blocks required to make the four major macromolecules within the body: carbohydrates, lipids, proteins, and nucleic acids.

Secondary metabolites, in contrast to primary metabolites, are dispensable and not absolutely required for survival. They, in contrast, are organic molecules that typically have an extrinsic function that mainly affects other organisms outside of the producer. Secondary metabolites are not essential for survival but do increase the competitiveness of the organism within its environment. They have a diversity of structures and include examples such as alkaloids, phenylpropanoids, polyketides, flavonoids and terpenoids.

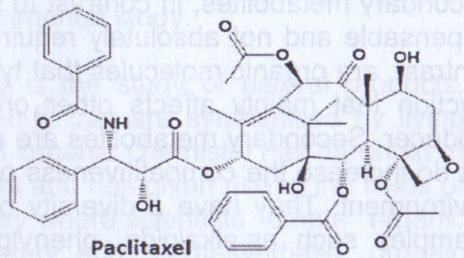
Natural products (secondary metabolites) may be extracted from the cells, tissues and secretions of microorganisms, plants and animals. A crude (unfractionated) extract from any one of these sources will contain a range of structurally diverse and often novel chemical compounds. The chemical diversity in nature is based on biological diversity. These active compounds can be used in drug discovery and development directly as they

are, or they may be synthetically modified to enhance biological properties or reduce side effects.

Phytochemistry is the bridge which connects chemistry and botany. When a chemical compound is isolated from a plant material the determination of its molecular structure and studies of its properties are distinctly that of a natural product chemist. Chemistry contributes to the methods of isolation, qualitative and quantitative determination of plant components. By application, this provides the necessary scientific explanation for plants observed responses (Burrell, 1937). The proper understanding of phytochemistry is essential for drug discovery and for the development of novel therapeutic agents against major diseases.

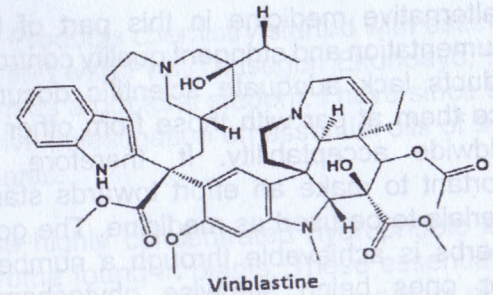
Biologically, some useful examples of natural products from plants include the anticancer agent spaclitaxel (Taxol) and vinblastine (from *Taxus brevifolia* and *Catharanthus roseus*, respectively), the antimalarial agent artemisinin (from *Artemisia annua*) and the opioid analgesic drug morphine (from *Papaver somniferum*). Figure 1

Taxus brevifolia



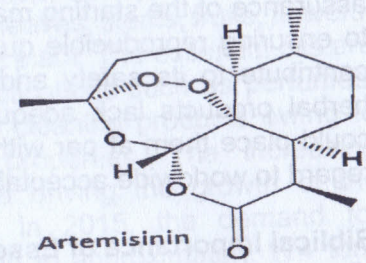
Paclitaxel

Catharanthus roseus



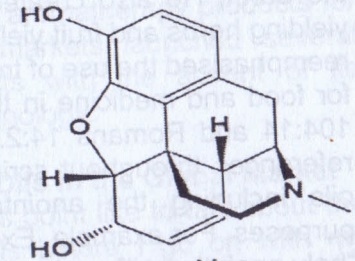
Vinblastine

Artemisia annua



Artemisinin

Papaver somniferum



Morphine

Figure 1: Examples of biologically active natural products from plants

Medicinal plants are moving from fringe to mainstream use with a greater number of people seeking herbal remedies for improvement and sustenance of their health (Saha *et al.*, 2010). However, a key obstacle, which has hindered the acceptance

of alternative medicine in this part of the world, is lack of documentation and stringent quality control. Most African herbal products lack adequate scientific documentation that could place them at par with those from other continents regarding worldwide acceptability. It, therefore, becomes extremely important to make an effort towards standardisation of plant materials to be used as medicine. The goal of standardisation of herbs is achievable through a number of techniques, the basic ones being stepwise phytochemical and bioactivity studies. These studies help in authentication and standardisation of the herbs. Accurate identification and quality assurance of the starting materials is an essential requirement to ensuring reproducible quality of herbal medicine which will contribute to its safety and efficacy. However, most African herbal products lack adequate scientific documentation that could place them at par with those from other continents with regard to worldwide acceptability.

Biblical Importance of Essential Oils

Vice-Chancellor Sir, there are biblical injunctions from God that support the use of plants for the healing of man and animal diseases. In the beginning, when God created the heaven and the earth, He also created among other things, grass, seed yielding herbs and fruit yielding trees for food and healing. God reemphasised the use of trees and leaves severally in the Bible for food and medicine in the Books of Ezekiel 47:12, Psalms 104:14 and Romans 14:2. Furthermore, there are numerous references throughout scripture regarding the use of fragrant oils including the anointment oil for health and healing purposes. For example, Exodus 30:23-25 describes the use of "holy anointing oil" such as, Olive oil, Cinnamon, Cassia. Other scriptures supporting these facts include, 1 Samuel 10:1, Exodus 25:6; 31:11; 30:23-35; 35:8, 28, 2 King 4:1-7, Proverbs 21:20, Psalm 23:5 Luke 7:46, Mark 6:13, James 5:14-15. All these perhaps lay a good ethno-botanical foundation for us today as scientists to research into these plants and natural products.

ESSENTIAL OILS

My interest in Natural Products chemistry started with essential oils and it began in 1996 with Prof. Olusegun Ekundayo, FAS when I joined his team as a doctoral student. I have since then carried out an extensive investigation on essential oils of some Nigerian medicinal plants.

Essential oils are the highly concentrated hydrophobic liquid containing volatile aroma found in plants. These essential oils are termed ethereal oil or volatile oil having aroma from plants. The oil is obtained from various herbs and plants including orange, peppermint, corn mint, lemon, eucalyptus, and others. The oil is obtained by extraction of leaves, stems, fruits, flowers, seeds, roots and other parts of the plant. The essential oils are applicable in a wide range of applications such as perfumes, soaps, cosmetics and household cleaning products owing to their antiseptic and antibiotic properties. The increasing applications of essential oils are driving the growth of the market. According to Statistics in 2015, the demand for essential oils worldwide amounted to approximately 174 tons and is forecast to reach around 245 tons by 2020. The rising demand for essential oils is also one of the boosting factors for the market. For instance, in November 2017, Organic Aromas, maker of a wide range of premium aromatherapy products for the home and professional-use markets launched several exciting and unique new products with the advent of its proprietary Nebulizing Diffuser technology.

Current and Future of Essential Oils in the Global Market

Mr Vice-Chancellor Sir, I will at this point like to talk about the global importance of essential oils before I go on with my contributions in this field.

The overall essential oils industry has seen significant growth in recent years. Changing consumer lifestyles, as well as rising disposable income of the consumers in developing countries is stimulating the growth of this market. The rising consumer awareness about the ill-health effects of synthetic chemicals used for adding texture &fragrances and for increasing the

aesthetic appeal of food products and increased awareness about health benefits associated with the consumption of essential oils has contributed towards the growth of global essential oils market.

Global Essential oils Market will cross USD 13 billion by 2024; Nigeria's Importation of Essential oils, perfumes, cosmetics, toiletries was US$322.72 Million during 2017, according to the United Nations COMTRADE database on international trade according to reports by Global Market Insights, Inc.

Growing elderly population suffering from various ailments and searching for potential herbal treatments to avoid side effects of pharmaceutical chemical drugs has driven aromatherapy industry growth, thereby propelling essential oils market size. Changing standards of living has led to the occurrence of various mental issues such as depression, insomnia, anxiety and stress which has grown the popularity of aromatherapy. Essential oils such as lemon, lavender, sandalwood, jasmine, orange and rosemary oils help in combating these issues which are likely to drive market growth.

Essential oils find application in pharmaceutical drugs owing to their fungicidal, bactericidal, antiparasitic, insecticidal and virucidal effects which promote its application to treat skin disease, dental issues and respiratory problems. Growing R&D expenditure in the pharmaceutical industry to innovate new active ingredients along with examining essential oils activity in cancer treatment will foster product demand. Hence, essential oils play a vital role in treating dermatological issues such as acne, eczema, rashes & hives, psoriasis which makes them suitable for skincare cosmetics, thus stimulating industry growth. Increasing consumer alertness towards synthetic chemicals in cosmetic products and their harmful effects will surge essential oils demand.

Essential oils market size from cleaning & home care application only is anticipated to exceed USD 550 million by 2024. Growth in the hospitality market along with companies

introducing products with additional benefits including germ fighting, better cleaning, fragrance, easy to use packs is likely to stimulate product demand in this sector.

Key Findings on the essential Oil Market

- The global essential oil market is projected to reach USD 18,956 million by 2023 with a growth rate of 5.92%.
- Globally, the application of essential oil in aromatherapy is growing at a higher rate of 6.19%.
- Globally, corn mint and orange essential oils held more than 57% of the market share in the year 2017.

Essential Oils markets are thriving in the U.S., Canada, Mexico, Germany, UK, France, Italy, Russia, Spain, China, India, Japan, South Korea, Australia, Indonesia, Thailand, Malaysia, Brazil, Saudi Arabia, UAE and South Africa. It is high time Nigeria also keyed in to the essential oil business and market to add to the revenue of our dear country.

Growing investments in research to develop microencapsulation for these products to ensure stability and quality to preserve them for flavouring application in beverages is likely to stimulate essential oils demand in this sector. In addition, technology advancement has examined its usage as an antioxidant edible packaging film for food & beverage which may foster industry growth.

Global Encapsulated Flavours and Fragrances Market revenue was worth at over USD 6 billion in 2017 and will witness over 4.5% growth, driven by technological developments coupled with increasing R&D investment by 2024. While Global Food Encapsulation Market outlook was worth over USD 27 Billion in 2016 and will witness a growth of over 6% by 2024, this growth is envisaged to be propelled by increasing investments in R&D for food preservation through encapsulation of colour, enzymes and preservatives.

The global essential oils market is segmented on the basis of product into:

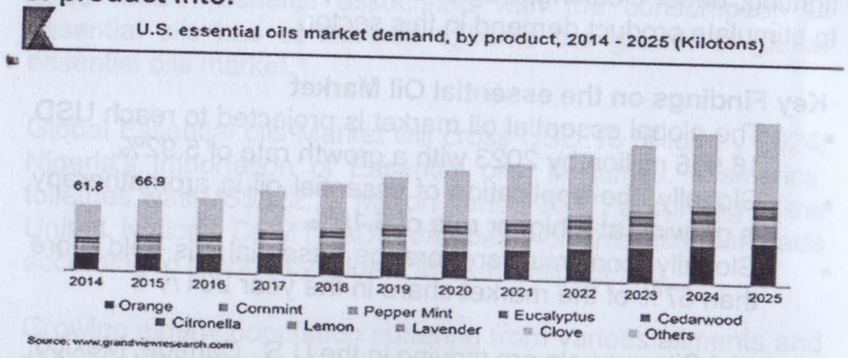


Figure 2: US, Essential Oil Market Demand
Source: https://www.grandviewresearch.com/industry-analysis/essential-oils-market

The global essential oils market is segmented on the basis of application into:

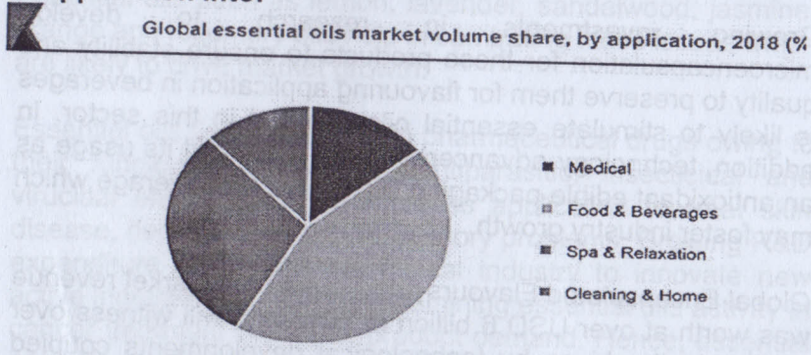


Figure 3: The Global Essential Oils Market
Source: https://www.grandviewresearch.com/industry-analysis/essential-oils-market

Mu'azu, Okonkwo, & Abdullahi, (2009) opined that the commercial production of essential oil in Nigeria is highly profitable and should be attractive to any potential investor. Apart from the fact that the essential oil domestic market is grossly under-serviced, the product has great export potential

particularly to Europe, Asia and West Africa sub- Saharan region aimed at attracting foreign earning to our country.

However, Stringent storage and transportation condition in addition to commercial manufacturing is labour-intensive, incurring additional cost that hamper industry profitability, thus affecting essential oils market price trends. Also, health issues concerning excessive use and suitability of the product to consumers may act as another restraining factor. Mu'azu, Okonkwo, & Abdullahi, (2009) concluded that the commercial production of essential oil using the steam distillation method is highly profitable and should be attractive to any potential investor. Apart from the fact that the domestic market is grossly under-serviced, the product has great export potential particularly to Europe, Asia and West Africa sub-Saharan region aimed at attracting foreign earnings to our country. It is therefore strongly recommended that both state and local governments in Nigeria should focus on establishing such a pilot plant in their respective domain, particularly where the raw materials are in abundance. This would help in alleviating poverty by creating job opportunities for teeming unemployed youths. I will conclude this section by adding that the shifting trend towards preventive healthcare, coupled with an improved standard of living among consumers, are the major factors driving the essential oils market. Also, increasing cases of depression and anxiety disorders among consumers are seen to be contributing to the growing demand for essential oils.

Jennifer Abraham wrote in Punch, February 21, 2013 (Essential oils: A viable value-added enterprise) that local production of essential oils is insignificant in Nigeria, hence; nearly 100 per cent of the essential oils used by our local industries are imported. Research statistics from the Raw Materials Research and Development Council, RMRDC indicate a local demand of over 100,000 kg annually; a figure that could be met through local production efforts. Reports have it that this country spent about $14m on the importation of Essential oils between June and December 1994 alone, this steadily increased to US$322.72 Million in 2017.

CHEMISTRY OF ESSENTIAL OILS

Essential oil constituents belong mainly to two chemical groups: terpenoids (monoterpenoids and sesquiterpenoids of low molecular weight) and, to a lesser extent, phenylpropanoids (Regnault-Roger *et al.,* 2012). The terpenoids sometimes referred to as isoprenoids, are a large and diverse class of organic compounds, produced by a variety of plants, particularly conifers, which are often strong smelling and thus may have had a protective function. They are the major components of resin, and of turpentine produced from resin. The name "terpene" is derived from the word "turpentine". Terpenes are major biosynthetic building blocks within nearly every living creature. Steroids, for example, are derivatives of the triterpene squalene (Ahmed, 2015). When terpenes are modified chemically, such as by oxidation or rearrangement of the carbon skeleton, the resulting compounds are generally referred to as terpenoids. The terpenoids, sometimes referred to as isoprenoids, are a large and diverse class of naturally occurring organic chemicals, derived from five-carbon isoprene units assembled and modified in thousands of ways. Terpenoids are the primary constituents of the essential oils of many types of plants and flowers. Essential oils are used widely as natural flavour additives for food, as fragrances in perfumery, and in traditional and alternative medicines such as aromatherapy (Gutiérrez *et al.,* 2012). Synthetic variations and derivatives of natural terpenes and terpenoids also greatly expand the variety of aromas used in perfumery and flavours used in food additives (Ijoma, 2007). The structure of terpenes is consistent with the joining together of the isoprene (C_5H_8)units as the building block, usually in a head-to-tail fashion (Bauer *et al.*, 2001, Bhat *et al.*, 2008).

Terpenes are therefore classified based on the number of isoprene units (C_5) that have been joined in this head to tail fashion (Table 1).

Table 1: Classification of Terpenes

S/N	TERPENES	ISOPRENE UNITS	CARBON ATOMS
1.	Monoterpenes	2	10
2.	Sesquiterpenes	3	15
3.	Diterpenes	4	20
4.	Sesterterpene	5	25
5.	Triterpene	6	30
6.	Carotenoids	8	40
7.	Rubber	> 100	> 500

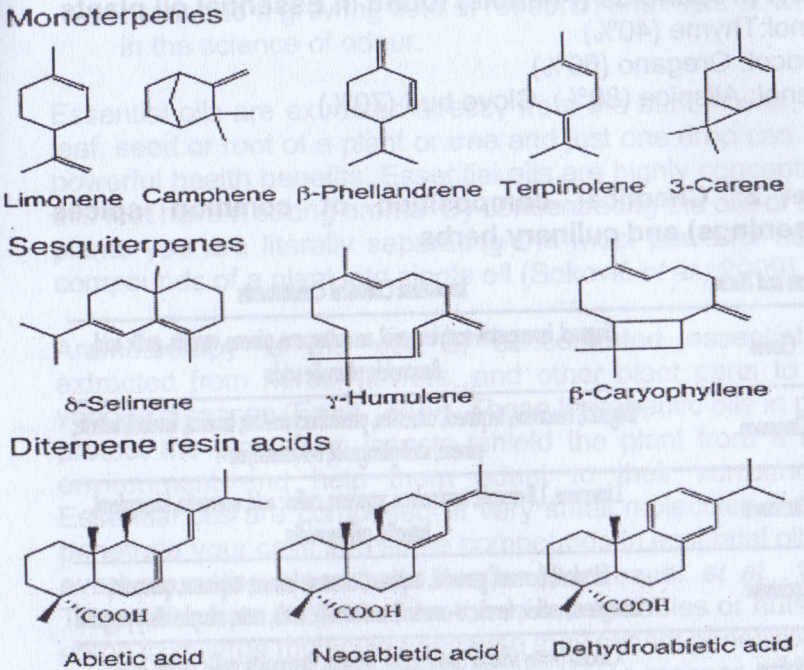


Figure 4: Terpenoids classes and examples

Monoterpenoids found in some common Essential oil plants

Limonene found majorly in citrus fruits, such as, Grapefruit (93%), Sweet Orange (89%), Lemon (70%), Bergamot (38.4%).
Linalool: Rosewood (90%), Lavender (37%)
Terpinen-4-ol: Tea tree (40%)
Menthol: Peppermint (45%)
Geraniol: Citronella (25%), Geranium (20%)

Sesquiterpenoids found in Essential oil plants

Beta-caryophyllene ($C_{15}H_{24}$ bicyclic) found majorly in Black Pepper (34%), Patchouli (20%), Ylang Ylang (10.5%).
Farnesol: Jasmine (10%), Ylang ylang (2%)
Patchoulol: Patchouli (40%)

Phenyl propanoids (Phenols) found in Essential oil plants

Thymol:Thyme (40%)
Carvocol: Oregano (60%)
Eugenol: Allspice (80%), Clove bud (70%)

Table 2: Chemical composition of common spices (seasonings) and culinary herbs

Spices and Herbs	Important Chemical Constituents
Cloves	Eugenol, isoeugenol, acetyleugenol, sesquiterpene, pinene, vanillin, gallic acid, flavonoids, phenolic acids
Cinnamon	Eugenol, limonene, terpineol, catechins, proanthocyanidins, tannins, linalool, safrole, pinene, methyleugenol, benzaldehyde
Cardamon	Limonene, 1,8-cineole, terpinolene, myrcene, caffeic acid, quercetin, kaempferol, luteolin, pelargonidin
Coriander	Linalool, borneol, geraniol, terpineol, cumene, pinene, terpinene, quercetin, kaempferol, caffeic, ferulic, n-coumaric and vanillic acids, rutin, tocopherols, pyrogallol
Saffron	Crocins (water soluble carotenoids), safranal, flavonoids, gallic, caffeic, ferulic, n-catechuic, syringic, salicylic, and vanillic acids
Turmeric	Curcumins, essential oils, eugenol, carotene, ascorbic acid, caffeic, p-coumaric, protocatechuic, syringic, vanillic acid

Industrial Uses and Applications of Essential Oils

Essential oils are unique and widely known for their scents, flavours and medicinal properties. Consequently, their uses are multifaceted. Two major basic applications could be recognised:

(a) Industrial - as flavour and fragrance material in perfumery;
(b) Medicinal - as expectorants, home remedies, conventional and alternative medicines. Industrially, essential oils remain the basic raw material for perfumers and flavourists. The odourant attributes of their products are solely due to essential oils. Perfumery compositions for fine fragrances, toiletries and house products are of essential oil origins. The widespread industrial utilisation has led to a growing field of research and rapid advances in the science of odour.

Essential oils are extracted directly from the bark, flower, fruit, leaf, seed or root of a plant or tree and just one drop can have powerful health benefits. Essential oils are highly concentrated oils that have a strong aroma. By concentrating the oils of these plants you are literally separating the most powerful healing compounds of a plant into single oil (Soković *et al.*, 2009).

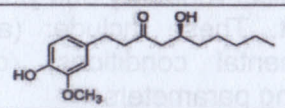
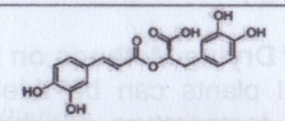
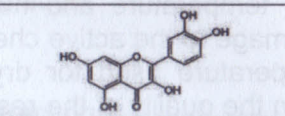
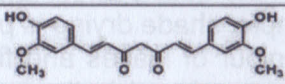
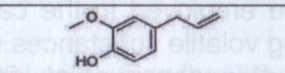
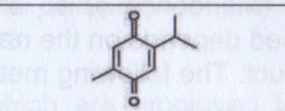
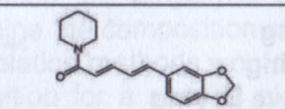
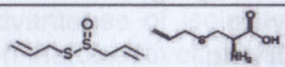
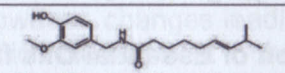
Aromatherapy is the use of concentrated essential oils extracted from herbs, flowers, and other plant parts to treat various diseases (Ernst, 2009). These therapeutic oils in plants protect the plant from insects, shield the plant from a harsh environment and help them adapt to their surroundings. Essential oils are composed of very small molecules that can penetrate your cells and some compounds in essential oils can even cross the blood-brain barrier (Buchbauer *et al.*, 1994). They differ from fatty oils (like those in vegetables or nuts) that come from large molecules because they cannot penetrate your cells so they are not therapeutic in the same manner.

- Essential oils have been shown to possess antibacterial, antifungal, antiviral, insecticidal and antioxidant properties (Burt *et al., 2004).*
- Some oils have been used in cancer treatment (Kordali *et al., 2005).*
- Some other oils have been used in food preservation (Sylvestre *et al., 2006).*
- Some have been used in aromatherapy (Wahba *et al., 2010)* and fragrance industries (Padmavathi *et al., 2013).*
- Essential oils are a rich source of biologically active compounds. There has been an increased interest in looking at antimicrobial properties of extracts from aromatic plants particularly essential oils (Van de Braak *et al., 1999).*
- Plant compounds in these oils have specific as well as general antimicrobial activity and antibiotic potential (Milhau *et al., 1997).*
- Essential oils such as aniseed, calamus, camphor, cedarwood, cinnamon, citronella, clove, eucalyptus, geranium, lavender, lemon, lemongrass, lime, mint, nutmeg, orange, palmarosa, rosemary, basil, vetiver and wintergreen have been traditionally used by people for various purposes in different parts of the world. Cinnamon, clove and rosemary oils had shown antibacterial and antifungal activity (Lawless, 2013).
- Cinnamon oil also possesses antidiabetic property (Shaik *et al., 2014).*
- Anti-inflammatory activity has been found in basil (Singh*et al.,* 1999).
- Lemon and rosemary oils possess antioxidant property (Padmavathi *et al., 2013).*
- Peppermint and orange oils have shown anticancer activity (Arias *et al.,* 2005). They help with nausea, vertigo, and exhaustion and also good for headaches.
- Citronella oil has shown an inhibitory effect on biodegrading and storage-contaminating fungi (De Billerbeck *et al.,* 2001).

- Lime oil has shown immunomodulatory effect in humans (Arias *et al.,* 2005).
- Lavender oil has shown antibacterial and antifungal activity; it was also found to be effective in treating burns and insect bites (Cavanagh *et al.*, 2002). It helps to alleviate stress, anxiety, irritability mental fatigue, panic attacks and depression, and also good for bruises and stretch marks.
- Tea Tree – disinfecting and good for skin blemishes and acne.
- Frankincense – used for immune system stimulation and to help with asthma, coughing and bronchitis.

Figure 5: Some Common terpenoids and their source

Table 3: The major biologically active compounds found in spices and herbs (Yashin, *et al.*, 2017)

Spices	Active Substance	Formula
Ginger	Gingerol	
Rosemary	Rosmarinic acid	
Onion	Quercetin	
Turmeric	Curcumin	
Cloves	Eugenol	
Fennelflower	Thymoquinone	
Black pepper	Piperine	
Garlic	Allicin, S-allyl cysteine	
Red pepper	Capsaicin	

Factors that Affect Essential Oils Quality in Plants

The presence, yield and composition of essential oils in plants which determine the quality of essential oils can be affected in a number of ways, from their formation of the oils in the plant to their final isolation. Several of the factors of influence have been studied, in particular for commercially important crops, to optimise the cultivation conditions and time of harvest and to obtain higher yields of high-quality essential oils that fit market requirements. In addition to the commercial importance of the

variability in yield and composition, the possible changes are also important when the essential oils and volatiles are used as chemotaxonomic tools. Knowledge of the factors that determine the chemical variability and yield for each species are thus very important. These include: (a) physiological variations; (b) environmental conditions; (c) geographic variations; (d) processing parameters.

Effect of Drying Methods on Essential Oil Plants

Medicinal plants can be dried in a number of ways when possible, temperature and humidity should be controlled to avoid damage to the active chemical constituents. The method and temperature used for drying may have a considerable impact on the quality of the resulting medicinal plant materials. For example, shade drying is preferred to maintain or minimise loss of colour of leaves and flowers; and lower temperatures should be employed in the case of medicinal plant materials containing volatile substances. The drying conditions should be recorded (Mendonça *et al.*, 2006). Therefore, the method of drying used depends on the nature of the plant and the desired end product. The following methods of drying are possible:

Air Drying
Sun Drying
Microwave Drying
Oven Drying
Freeze-Drying

Extraction of Essential Oils from Plants

The major methods of extraction of essential oils are distillation, carbon dioxide extraction, cold press extraction, and solvent extraction methods. Other commonly used methods are microwave assisted extraction and supercritical fluid extraction. The distillation method of extraction is most widely used especially for commercial purposes compared to other extraction methods since it yields the purest form of essential oil. Different types of distillation methods are used such as water distillation (Hydrodistillation), water & steam distillation, and steam distillation for extraction of oils. The main advantages of

the distillation method are quality control and wide application usage.

Methods of Essential Oil Preparation are listed below:

1. Distillation
   (a) Steam distillation
   (b) Hydrodistillation
   (c) Hydrodiffusion
   (d) Flash distillation
   (e) Vacuum distillation
   (f) Carbon dioxide distillation
2. Extraction
   Solvent extraction
   Supercritical inert gas extraction
3. Head Space Extraction
4. Miscellaneous Methods
   - Freeze concentration
   - Expression-mechanical cold press for Citrus peels
   - Enfleurage for Flowers

The methods or procedures which are employed to isolate essential oils from plants determine the composition of the oils. It is unlikely that two different isolation methods would produce volatile oils of identical composition for a specific plant or its organs. The drawbacks and advantages of isolation method over the others are dependent on the objectives of the study of the essential oil composition. However, changes leading to the formation of new compounds which did not exist in the original plant is not a desirable phenomenon. Supercritical carbon dioxide is increasingly being used in research laboratories and industrial settings to extract essential oils from plant materials. The advantage of this procedure is that the carbon dioxide ultimately reverts to gas and the petrochemical residues which originate from normal organic solvents are avoided. The lower temperature of extraction prevents the decomposition or alteration of the essential oil constituents and the product nature is identical, as much as possible.

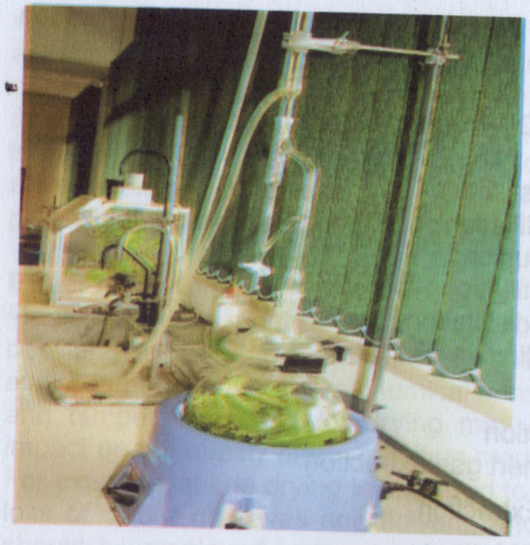
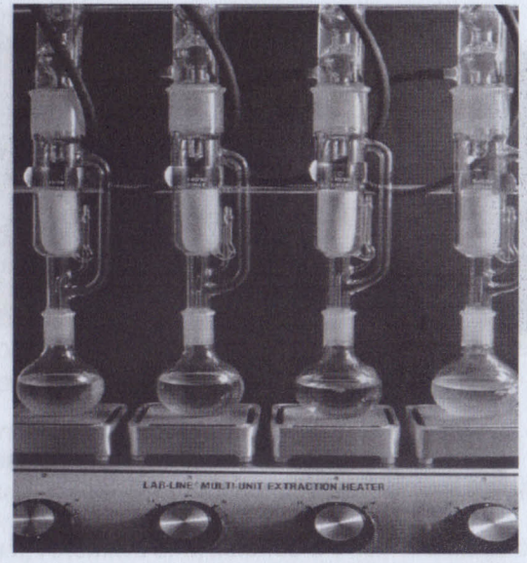


Figure 6: Hydrodistillation setup (Clevenger apparatus)

Figure 7: Steam distillation setup



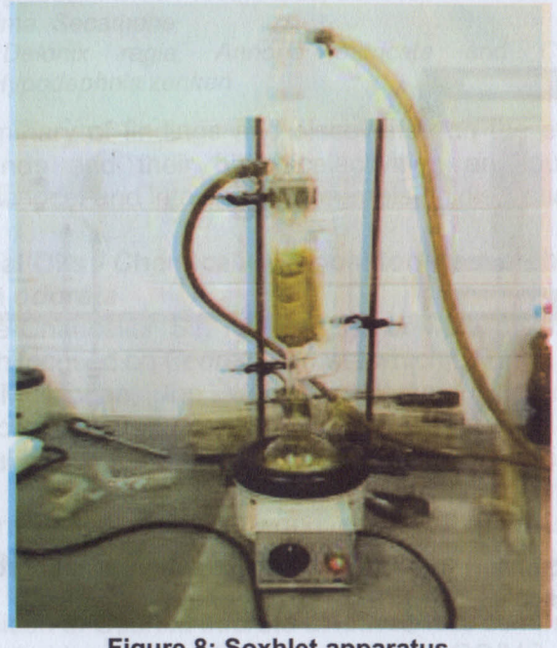
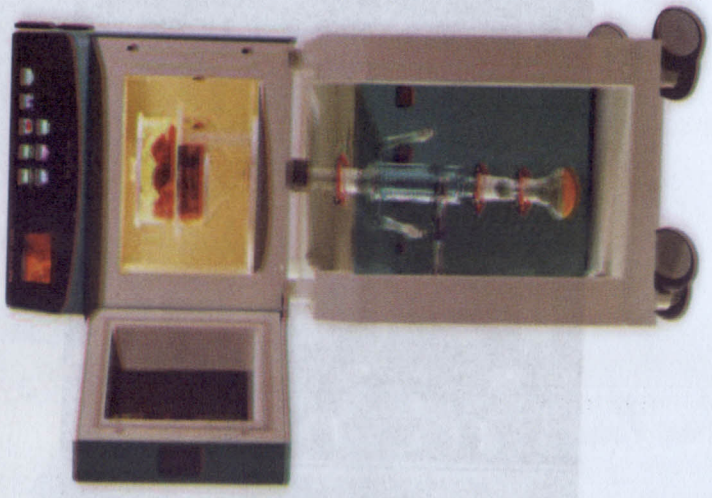


Figure 8: Soxhlet apparatus



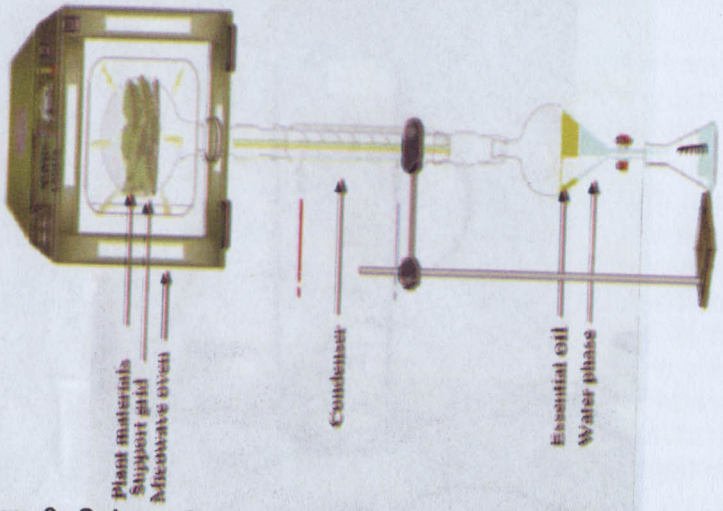


Figure 9: Solvent free microwave extraction at laboratorial and industrial scale

MY CONTRIBUTIONS TO KNOWLEDGE

My research interests are in three areas:

- Essential oil Research
- Phytochemistry
- Organic Compounds Synthesis

ESSENTIAL OIL RESEARCH CONTRIBUTIONS

In the last 23 years, we have made collaborative efforts in our laboratory to investigate indigenous aromatic medicinal and economic plants. We have validated and documented the chemical composition and biological activities of the following aromatic plants found in Africa.

Cedrela odorata, Hyptis suaveolens, Costus afer, Xylopia aethiopica, Daniellia ogea,
Solanum aculeastrum, Solanum pseudocapsicum, Mentha longifolia, Helichrysum
odoratissimum, Artemisia afra,Calendula officinalis,Citrus aurantifolia, Morinda lucida,
Parkia Biglobosa,Abrus Precatorious, Leonotis leonurus, Caesalpinia Pulcherrima, Secamone
afzelii, Delonix regia, Annona muricata and *Cymbopogon citratus.Hypodaphnis zenkeri*

The summary of findings and discoveries on the essential oil compounds and their biologicalactivities are published in reputable local and international journals as discussed below:

Essential Oils - Chemical Composition Research

Cedrela odorata

Mr. Vice-Chancellor Sir, my first set of work on essential oil research focused on *Cedrela odorata* which belongs to the plant family Meliaceae, the wood is commonly used in the manufacture of furniture and cigar boxes. The wood also yields essential oils which possess characteristic woody and fragrant odours. The plant is also employed ethnomedicinally in the treatment of asthma. The wood essential oil is used in the household products industry for imparting fragrant odour to soaps, disinfectants and air-fresheners. The essential oil composition of *Cedrela odorata* L. leaves was comprehensively investigated by means of capillary GC and GC/MS. Twenty-six

constituents were identified in the volatile oil. Sesquiterpenoids such as α-santalene (9.5%), β-acoradiene (7.1%), β-elemene (6.8%), caryophyllene oxide (6.0%) and Z- α-bergamotene (6.0%) were the dominant compounds. Minor constituents included isocaryophyllene, β-bisabolene, β-alaskene and amorpha-4, 11-diene. A rare sesquiterpenoid sulphur derivative, mintsulphide, was identified for the first time in *C. odorata* essential oil.

Table 4: Composition of leaf essential oil of *Cedrela odorata* L

GC	KI[b]	MS(EI)*m/z*ions[c]	Composition (%)	Compound
1	8	-	12.5	Ui[e]
2	9	136,93,41,77	0.6	*a*-Pinene[f]
3	9	138.81.41.53	t[d]	2-Pentvlfuran
4	1026	136,68,93,41	0.2	Limonene
5	1193	-[g],43,95,41	0.1	Bornylacetate
6	1343	204,105,41,119	0.1	-Cubebene
7	1368	204,161,119,105	2.9	-Copaene
8	1381	204,81,93,68	6.8	-Elemene
9	1394	204,41,93,69	4.2	*iso*-
1	1398	204,41,69,161	1.3	3-Cedrene[f](*j*)-
1	1405	204,41,93,94	9.5	-Santalene[f]
1	1411	204,41,93,69	2.6	-Caryophyllene
1	1428	204,93,110,41	6.0	Z- -Bergamote
1	1432	204,41,94,93	1.0	*epi*- -Santalene[f]
1	1440	204,93,80,121	2.9	-Humulene
1	1447	204,121,119,93	3.5	Amorpha-4,11-
1	1454	204,119,93,121	7.1	Acoradiene
1	1459	-	1.3	Ui[e]
1	1463	204,41,93,121	1.0	Isobicyclogermac
2	1467	204,41,69,93	0.7	*E*- -Bergamotene
2	1471	204,41,93,79	1.0	-Humulene
2	1488	204,121,136,93	3.6	-Alaskene
2	1497	204,41,69,93	3.8	-Bisabolene
2	1507	204,161,134,119	2.2	-Cadinene
2	1556	220,41,79,93	6.0	Caryophylleneoxi
2	1574	220,41,43,67	1.3	Humuleneoxide[f]
2	1580	-	1.6	Ui[f]
2	1629	-	1.6	Ui[f]
2	1644	236,123,79,41	0.3	Mintsulphide[f]
3	1868	220,41,91,105	1.9	14-Oxy-2-

aGC peaks (elution order on Cpsil 5 capillary column). bKovaÂ ts indices on Cpsil 5 (equivalent to OV-1) column. c Major mass spectral ions: M. (molecular ion), base peak, two other characteristic ions in decreasing order of relative abundance. d t . Trace amount (50.1%). e Ui . Unidenti®ed compounds (40.5%). fReported for the first time as constituent of *Cedrela odorata* essential oil. gM. absent.

Costus afer

The plant *Costus afer* bears white and yellow flowers, it is mainly found in the forest region of Nigeria, South Africa, Guinea, Niger and Sierra Leone. Various parts of the plant are used for the treatment of different ailments, such as rheumatism, eye drops for various infections, headache, cough, diuretic, urethral discharge and malaria. The absence of reports on the leaf essential oil composition of this plant in literature prompted this study by Asekun and Adeniyi (2003). Detailed systematic and comprehensive analysis of the essential oil of the leaves of *Costus afer* Ker-Grawl (Zingiberaceae) from the western part of Nigeria by capillary gas chromatography (GC) and gas chromatography-mass spectrometry (GC-MS) led to the identification of 27 compounds. The results showed that sesquiterpenoids were the most abundant group of volatile compounds, with sesquilavandulyl acetate (17.0%) as the principal component. β-caryophyllene (12.3%) and Z, α-farnesol (9.9%) were also present in reasonable quantities. Investigation of the antimicrobial activity of the essential oil showed that it is inactive.

***Daniellia ogea* L**

A number of species of *Daniellia* (Leguminosae) yield a balsam or oleo-resin that dries to a fragrant resin called *'gum copal'* in West Africa. The gum resin is a yellow or brown viscous liquid with a resinous odour to scent garments or rid them of vermin and to fumigate huts. The plant wood is reputed to yield a pale yellow volatile oil with a faint aromatic odour. But the chemical literature does not contain any previous report on the detailed chemical composition of the leaf oil *of Daniellia ogea* L. hence the investigation by capillary gas chromatography (GC) and gas chromatography/mass spectrometry (GC/MS). This led to the identification of 31 compounds in the oil. The oil was found to be rich in sesquiterpenoids. The major compound was caryophyllene oxide (20.1%). Humulene oxide, α-humulene and β-selinene were also found in moderate amounts of 6.9%, 3.8% and 3.8%,

Table 5: Chemical composition (%) of the leaf oil of *Daniellia ogea*

Compound	RI	%	Identification methods	Compound	RI	%	Identification methods
benzaldehyde	947	0.4	GC,[1] MS	(E,E) -farnesene	1485	1.2	GC,[1] MS
6-methyl-5-hepten-2-one	972	1.2	GC,[1] MS	(Z)-dihydrofamesal'	1497	1.1	GC,[2] MS
2-pentyl furan	984	0.3	GC,[1] MS	(Z)- -bisabolene	1500	1.0	GC,[1] MS
phenylacetaldehyde	1020	0.4	GC,[1] MS	trans-calamenene	1519	0.4	GC,[1] MS
limonene	1023	1.7	GC,[1] MS	isocaryophyllene oxide	1548	1.7	GC,[1] MS
-copaene	1369	0.4	GC,[1] MS	marsupellol"	1553	3.4	GC,[2] MS
-elemene	1376	3.4	GC,[1] MS	spathulenol	1576	t	GC,[1] MS
cis- -bergamotene	1382	1.2	GC,[1] MS	caryophyllene oxide	1557	20.1	GC,[1] MS
frans- -bergamotene	1412	0.6	GC,[1] MS	gleenol	1566	0.8	GC,[1] MS
-caryophyllene	1418	t	GC,[1] MS	humulene oxide"	1581	6.9	GC,[1] MS
-humulene	1428	3.8	GC,[1] MS	germacrene D-4-ol	1588	1.2	GC,[1] MS
amorpha-4, 11 -diene	1440	1.3	GC,[1] MS	selin-11-en-4-a-ol	1652	t	GC,[1] MS
-acoradiene	1454	2.5	GC,[1] MS	zizanal	1619	0.5	GC,[1] MS
-neoclovene	1459	0.7	GC,[1] MS	(E,Z)-farnesol	1634	1.4	GC,[1] MS
-selinene	1471	3.8	GC,[1] MS	(E)-sesquilavanduly lactate	1705	3.0	GC,[1] MS
-alaskene	1482	1.7	GC,[1] MS				

RI = retention index; GC[1]: retention index on the basis of authentic compounds; GC': retention index from literature and data bank; MS: mass spectrum; 'tentative identification on the basis of MS; "correct isomer not identified; t = trace (< 0.1 %); 'also known as longipin-3(15)-en-4-ol; mass spectra of tentatively identified compounds: a) GC peak 19—dihydrofarnesal ($C_{,5}H_{2<}O$), RI 1497, EIMS—m/z (RA %) 41(100), 69(92), 43(78), 81(51); b) GC peak 22—marsupellol ($C_{,6}H_{M}$), RI 1553, EIMS—m/z (R/A %) 41(100), 55(57), 67(55), 18(53) (main fragments in decreasing order of relative intensities)

Solanum Species

In furtherance of our research work on essential oil research, four *Solanum* species were studied for their volatile constituents. Plant species in the genus *Solanum* are known to be rich in steroidal glycoalkaloids and sesquiterpenoids (Cipollini and Levey (1997); Nagoka *et al.*, (2001); Shamim (2004).

Solanum aculeastrum

Solanum aculeastrum Dunal, known as goat bitter apple, is native to Africa and widely distributed in South Africa. It is a multi-branched shrub, 1-5 m high, usually heavily armed with compressed prickles. The flowers are white and produce berries which are yellow-green in colour when ripe. It grows in the areas of high rainfall of more than 700 mm per year and at altitudes from 275 to 1780 m. The extremely bitter fruit of this species is used medicinally in various ways. The fresh and boiled berries of the plant are used as a cure for jigger wounds, gonorrhoea and for the treatment of acne (Kokwaro, 1993; Agnew and Agnew, 1994). The leaves of *Solanum aculeastrum* yielded 31 volatile compounds, representing 84.5% of the total oil composition. The oil was found to consist mainly of alkanes (17.5%), aldehydes (17%) and aromatic hydrocarbons (15.2%). The major compounds were n-nonane (12.4%) and o-phthalic acid (11.8%). The hexane fraction of the methanolic extract of the berries of the plant was also subjected to GC-MS analyses, yielding 16 compounds, which accounted for 87.1% of the total volatiles. The fraction was dominated by alkanes/ alkenes with undecane (21.7%), tetradecane (10.8%) and tridecane (10.0%) being the most prominent (Asekun *et al.*, 2006).

Solanum pseudocapsicum

Solanum pseudocapsicum is a poisonous plant used in traditional medicine for the treatment of acute abdominal pain and in the treatment of boils and gonorrhoea and as a tonic for men. It contains the poisonous compound solanocapsine and other alkaloids that are reported to be fatal to humans and animals. The chemical compositions of hexane extractable fractions of the leaves of *Solanum pseudocapsicum* were

reported by Ailero *et al.*, (2006) to be dominated by aliphatic hydrocarbons with decane (44.1%), undecane (24.6%) and nonane (6.1%) as the main constituents, while the second fraction was dominated by decane (24.9%), undecane (13.0%), tetradecane (10.0%) and hexadecane (8.3%). The main constituents of the third fraction were nonane (20.7%) and α–terpinolene (7.2%). The acyclic diterpene phytol (35.8%), fatty acids (32.5%) and α-terpinolene dominated the fourth fraction.

Solanum aethiopicum

The African eggplant, *Solanum aethiopicum* also known as garden eggs or mock tomato is a deciduous plant. The crop appreciates the warm, non-humid conditions found throughout the Savannah belt of West and East Africa. It can grow on a wide range of well-drained soils, but cannot grow in the shade. The fruits can be eaten raw when unripe and cooked when fully ripe; it can also be used as a vegetable flavouring for other food. A report on the leaf essential oil of *Solanum aethiopicum* obtained by hydrodistillation also showed that twenty (20) compounds which accounted for 90.3% of the leaf oil were identified. The major compound was methyl eugenol (36.5%), other prominent compounds were phytol (19.0%), α-pinene (7.5%), g-gurjunene (5.9%) and methylisoeugenol (5.1%) (Asekun *et al.*, 2006c).

Solanum pseudocapsicum

In yet another report on the same species, Asekun *et al.*, 2007 revealed that the volatile components of *Solanum pseudocapsicum* roots analysed by gas chromatography-mass spectrometry gave a total of 41 compounds, representing 50% of the oil. The oil was found to contain fatty acids (26.8%), terpenoids (7.6%), and aldehydes (5.3%) as the major components. The dominant compounds were hexadecanoic acid (24.1%), 2-methoxy-3-isopropylpyrazine (2.8%), and 15-methylhexadecanoic acid (2.1%). Other notable components in the oil include β–elemene and γ-elemene. It was suggested that the high percentage of hydrocarbons, terpenes and fatty acids

might have contributed to the understanding of the medicinal properties of this species as a poisonous plant.

Callistemon viminalis

Asekun and Afolayan (2008) reported the leaf essential oil obtained from *Callistemon viminalis*, an exotic plant from South Africa. The yield of the essential oil was 0.57%. The oil is mainly composed of monoterpenes (99.1%), with 1,8-cineole as the main component (63.9%). Other significant monoterpenoid components included β-pinene (17.9%), α-phellandrene (4.9%), α-terpineol (2.8%) and α-pinene (2.0%). The sesquiterpenes, β-caryophyllene, spathulenol and α-guaiene represented minor components (<1%) of the oil.

Kigelia africana

Kigelia africana, commonly called the sausage tree, is of the Bignoniaceae family; it has 16 synonyms and common to South, Central and West Africa. The fruits of *Kigelia africana* (Lam.) Benth are a popular source of traditional medicine throughout Africa. The extracts from the stem bark have been widely analysed for pharmacolological activities, but the chemical composition knowledge of the fruits and leaves is limited, despite extensive use in traditional remedies. In the research report by Asekun *et al.*, (2007), *Kigelia africana* Benth commonly called sausage tree was obtained from Ijanikin, Lagos Nigeria and was investigated for its leaves and flowers volatile oil constituents The leaf oil was found to contain 25 components, while the flower oil contained 9. Both oils were rich in non-terpenoids while hexadecanoic acid (21.91%, leaf oil; 57.00%, flower oil) was the most abundant in both oils. The other major components were ethyl linoleate (21.73%) and α-pinene (12.28%) in leaf oil and terpenolene (8.26%), myristic acid (7.95%) and linalool (6.71%) in the flower oil.

***Citrus aurantifolia* Swingle**

Most often during the processing of lime fruits for essential oil extraction, rotten fruits are used along with ripe ones. In this study, Asekun and Afolayan (2008) reported that the volatile

constituents of the essential oils from both ripe and rotten lime fruits (*Citrus aurantifolia* Swingle) from Nigeria contained 55 and 49 components respectively. Limonene and citral, which are believed to be the two major citrus odour contributors, were present in both ripe and rotten lime oils. Aldehydes like decanal and the farnesenes, which are also important in citrus flavour, were represented in both lime oils. Some notable components of ripe lime fruit oil, like *trans*-β-ocimene, linalool, myrcenol, dodecanal, *trans*-β–bergamotene and *trans*-γ–bisabolene, were absent in the rotten fruit oil. It could be suggested that some compounds like *cis*–ocimene, *trans*-linalool oxide, *p*-mentha-3-en-1-ol, mentha-1,4,8-triene, citronellal, *trans*- β–bergamotene and α–copaene, which were not identified in the ripe fruit oil, were introduced into the lime oil by the incorporation of rotten fruits in the distilled samples.

Table 6: Essential oil components identified in both ripe and rotten fruits of *Citrus aurantifolia*

S/N	Oil composition		% Composition[a]	
				Rotten
1.	Butylacetate	798	0.6	0.8
2.	α-Pinene	941	1.9	1.4
3.	Camphene	947	0.2	0.3
4.	β- Pinene	978	13.1	8.4
5.	β–Myrcene	987	1.6	1.4
6.	α–Phellandrene	1008	0.3	0.3
7.	α–Terpinene	1019	0.9	0.9
8.	Limonene	1029	21.0	21.3
9.	γ-Terpinene	1057	8.3	8.9
10.	α–Terpinolene	1087	2.5	8.5
11.	Fenchol	1126	0.5	0.7
12.	β–Terpineol	1167	0.8	0.8
13.	Terpinene-4-ol	1178	2.7	3.3
14.	α-Terpineol	1188	11.7	14.1
15.	γ–Terpineol	1190		0.5
16.	*n*-Decanal	1192		0.6
17.	3-Cyclohexene-1-	1213		0.2
18.	Citral	1224		1.4
19.	Geraniol	1244		1.2
20.	Tridecane	1300		0.2
21.	δ-Elemene	1324		0.4
22.	Citronellyl acetate	1338		0.03
23.	Neryl acetate	1347		0.2
24.	Geranyl acetate	1365		0.2
25.	*trans*-β–	1429		0.4
26.	*trans*-β–Farnesene	1474		0.3
27.	β–Santalene	1516		0.2
28.	δ–Cadinene	1523		0.2
29.	Germacrene-D	1528		0.2
30.	*trans*-α-Bisabolene	1543		0.2
31.	*E*,*E*-α–Farnesene	1549		4.8
32.	α–Gurjunene	1562		0.2
33.	*cis*-α-Bisabolene	1566		0.1
34.	γ–Elemene	1570		0.2
35.	Hexadecanal	1634		0.1
36.	α–Bisabol	1655		0.2
37.	Octadecanal	1673		0.05
38.	Hexadecanoic acid	1675		1.2
39.	*n*-Heptadecane	1700		0.1
40.	Eicosane	2000		0.2

Table 7: Compounds identified in the essential oil of ripe *Citrus aurantifolia* only

S/N	Oil composition	KI	%
1	*cis*–Ocimene		0.6
2	*trans*-Linalool oxide	1099	0.7
3	*p*-Mentha-3-en-1-ol	1110	0.2
4	*p*-Mentha-1,4,8-triene	1114	0.1
5	Citronellal	1153	0.5
6	Myristic aldehyde	1378	0.4
7	*trans*-β–Bergamotene	1411	2.8
8	α–Copaene	1417	0.07
9	9,12-Octadecadienoic acid	2254	0.2
10	Tricosane	2302	1.0

Table 8: Compounds identified in the essential oil of rotten *Citrus aurantifolia* only

S/N	Oil composition	KI	%
1.	Nonane	900	0.3
2.	*trans*-β-ocimene	1026	0.2
3.	Linalool	1088	5.5
4.	Myrtenol	1171	0.2
5.	Terpineol	1184	0.2
6.	Cyclofenchol	1197	0.9
7.	β–Elemene	1437	0.4
8.	*n*-Dodecanal	1441	0.8
9.	*trans*–α–	1446	4.2
10.	β-Selinene	1486	0.1
11.	δ–Cadinene	1520	0.09
12.	*trans*-γ–	1521	0.05
13.	Aromadendrene	1523	0.06
14.	Hexadecane	1601	0.3

Hypodaphnis zenkeri

In a collaborative research work with the Department of Botany of this University, the systematic significance of *Hypodaphnis zenkeri* was studied. The plant is a monotypic taxon whose position is basal in the phylogenetic tree of the family Lauraceae. Cuticular information on the plant is lacking. Given the systematic relevance of this character in the family and absence of its record for the species, the leaves of the species were investigated with the aid of light and scanning electron microscopy. Only non-volatile chemical information about the species has been reported in the stem bark and leaves of the *Hypodaphnis zenkeri* (Momo *et al.* 2013, Moukette *et al.* 2014).

Therefore, this study documented the cuticular characters of the plant which hitherto was lacking and provide additional chemical characters that partly underlie the medicinal usefulness of the plant. Hence, volatile organic compounds in leaves and fruits were studied with Gas Chromatography-Mass Spectrometry (GC-MS), for the first time. Taxonomically useful cuticular features of the species include long stomatal rim and aperture, granulated periclinal walls on the adaxial surface and superficial stomatal orientation. The leaves and fruits of the plant are rich in volatile organic compounds such as 1,2-benzene-dicarboxylic acid, hexadecanoic acid ester and stigmasta-3,5-diene. Based on these features, the species can be distinguished from other related taxa in the family.

Table 9: Volatile organic compounds in the leaf and fruit of *Hypodaphnis*

Compound	Leaf	Fruit
Methyl ester	Present as hexadecanoic acid methyl ester	Present as octadecanoic acid methyl ester
Bis(2-ethylbutyl ester) phthalate	Present	Present

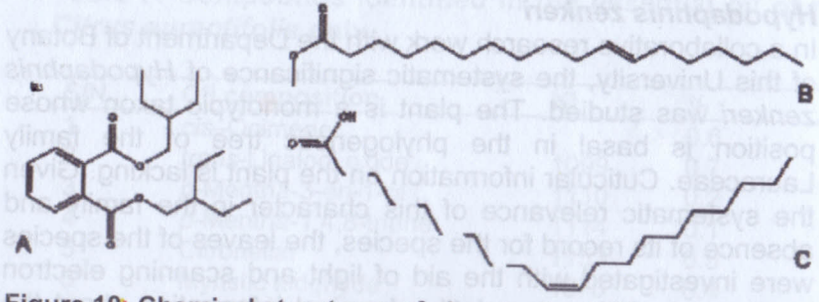


Figure 10: Chemical structures of abundant volatile chemicals in the leaf and fruit of *Hypo daphnis zenkeri* (Ariwaodo and Adesina)

A = 1,2 benzene dicarboxylic acid (bis 2-ethylbutyl ester);
B = 11-octadecanoic acid (methyl ester);
C = 9-octadecanoic acid (methyl ester)

Essential Oils- Effects of Drying Methods

Mr. Vice-Chancellor Sir, many medicinal plants used for the treatment of various diseases traditionally are usually processed (dried, pulverized and extracted) prior to administration. These processes affect the chemical composition and hence the quality of the oils, which could also influence their therapeutic or biological activities. The leaves of aromatic plants are often dried before extraction to reduce moisture content. During this process, many compounds which are dragged to the leaf surface by the evaporating water, are lost. The method of drying usually has a significant effect on the quality and quantity of the essential oils from such plants.
The knowledge of this prompted the need to carry out research on the effect of different drying and extraction methods on the yield, chemical composition and quality of the essential oils of some medicinal plants among which are *Mentha longifolia; Artemisia afra; Calendula officinalis; Leonotis leonurus; Helichrysum odoratissimum Caesalpinia pulcherrima;* to mention a few.

Mentha longifolia

A study by Asekun *et al.* (2007) investigated the effects of air, sun and oven methods of drying on the content and chemical quality of the essential oil of *Mentha longifolia*. The most prominent component in both the air-dried and sun-dried leaf oils was menthone (47.9% and 38.3%, respectively), limonene (40.8%) in oven-dried leaf oil, while, pulegone was the major component in the original fresh leaf oil. Menthone and pulegone were not detected in the oven-dried leaf oil. The essential oil underwent a significant chemical transformation in its monoterpenoids when the leaves were dried by the three different methods. Due to the significant reduction of the potentially harmful pulegone and menthone by oven-drying, the study suggested that this herb should be oven-dried or cooked before consumption in order to reduce toxicity.

Table 10: Chemical composition of the essential oil from *Mentha longifolia* leaves using different drying methods

No.	Compound	Kovat index	Plant material(leaves)			
			Fresh	Air-dried	Oven-dried	Sun-dried
1	α–Pinene	941	0.8	0	15.0	1.9
2	β-Pinene	954	5.7	4	4.2	8.0
3	Limonene	1014	–	t	40.8	–
4	1,8-Cineole	1015	13.0	16.4	t	16.6
5	χ-Terpinene	1040	–	–	1.5	0.3
6	*cis*-Sabinene	1051	1.2	2.1	–	1.7
7	Terpinolene	1074	–	–	0.5	–
8	β-Thujone	1092	–	–	–	0.7
9	Terpinene-4-ol	1178	–	–	0.7	–
10	Menthone	1182	31.1	47.6	t	38.3
11	Borneol	1188	3.3	t	–	–
12	*cis*-Isopulegone	1192	–	1	–	–
13	α–Terpineol	1193	0.7	0	0.4	0.5
14	Linalylpropanoate	1271	–	–	–	0.7
15	Myrtenol	1226	–	–	–	0.1
16	Pulegone	1280	35.0	18.4	–	20.2
17	Piperitone	1284	1.8	1	–	1.5
18	Bornylacetate	1306	–	–	0.2	–
19	Geraniolformate	1311	–	t	–	t
20	Piperitenone	1378	–	0	–	1.3
21	α-Terpinene	1382	–	–	0.2	–
22	α-Copaene	1417	–	–	1.7	–
23	β-Bourbonene	1428	0.1	0	–	0.1
24	β-Elemene	1437	0.1	0	–	0.1
25	*cis*-Jasmone	1446	0.2	0	–	0.2
26	β-Caryophyllene	1474	1.1	1	9.7	1.6
27	β-Cubenene	1482	t	–	–	
28	(*Z,E*)-α-Farnesene	1489	–	–	0.3	
29	Alloaromadendrene	1493	–	–	0.3	
30	β-Selinene	1499	–	–	0.2	–
31	α-Humulene	1511	0.1	0.1	1.8	t
32	Germacrene D	1513	1.1	2.5	–	2.1
33	Aromadendrene	1522	–	–	0.9	–
34	χ-Curcumene	1545	–	–	1.2	–
35	β-Pathoulene	1564	–	–	0.3	–
36	Bicyclogarmacrene	1568	0.1	0.3	–	0.4
37	GermacreneA	1575	–	–	0.6	–
38	χ-Cadinene	1601	t	t	0.8	t
39	χ-Selinene	1615	–	–	0.5	–
40	Caryophylleneoxide	1676	t	0.1	3.1	0.1
41	Viridiflorol	1692	–	3.3	–	
42	Isospathulenol	1746	–	–	–	t
43	T-Muurolol	769	–	–	–	–

Artemisia afra

Artemisia afra Jacq.ex Willd., a member of the Asteraceae, is commonly called wild wormwood or umhlonyane in South Africa, where it is one of the most widely used medicinal plants. The roots, stems and leaves are used in many different ways for the treatment of several ailments.

A study by Asekun *et al.* (2007) highlighted the effect of drying methods on the quality and quantity of the essential oil of *Artemisia afra*. The oil yield from the plant differed according to the drying methods; viz: 0.18%, 0.88%, 1.54% and 1.88% for fresh, oven-dried, air-dried and sun-dried oils respectively. Compounds such as a- and β –Thujone (52.1 - 39.8%), camphor (14.4 - 8.2%), 1, 8-cineole (21.8-13.1%) and borneol (7.8 - 2.7%) which are the major components responsible for the characteristic flavour of the herb, were present in significant amounts in the oils from the entire dried herb preparations. Generally, the drying methods had no significant effect on the monoterpenoids composition of the essential oils from *A. afra*.

Helichrysum odoratissimum

Another similar study reported by Asekun *et al.* (2007) observed an opposite trend in *Helichrysum odoratissimum* (a commonly used medicinal plant in South Africa), the chemical profile of *H. odoratissimum* was affected by the same drying methods utilised. There were noteworthy chemical alterations in the major components of the essential oils. The compounds pulegone and menthone were reported as potentially harmful compounds, hence their substantial reduction in the dried oils as compared to the fresh leaf oil is noteworthy as it aids the reduction of toxicity and hence improve the quality of the oils. The essential oil from the herb was extracted and characterised for the first time using different drying methods.

Calendula officinalis

In furtherance of our work on the effect of drying methods on essential oil quality, *Calendula officinalis* is an aromatic herb that belongs to the Asteraceae family. While the biennial form grows wild in Southern, Eastern and Central Europe (Van Wyk

and Wink, 2004), the annual form is more widely cultivated. The leaves and flowers of *C. officinalis* have a wide range of culinary usage in South Africa and because of their colour, aroma and flavour, they are used in food preparation to enhance taste and appearance. The essential oil is highly medicinal (Janke, 2004) with several therapeutic activities such as anti-inflammatory, antitumorigenic (Jimenez-Medina *et al.*, 2006), antimicrobial (Sarrell *et al.*, 2003) and anti-HIV-1 replication (Kalvatchev *et al.*, 1997). In our study, the fresh leaf, dry leaf and fresh flower oils of the herb yielded 0.06, 0.03 and 0.09% respectively. Sesquiterpenoids dominated the fresh leaves (59.5%) and flowers (26%), while the monoterpenes dominated the oil in the dry leaves (70.3%). T-muurolol (40.9%) predominated in the fresh leaf oil; α-thujene (19.2%) and decadinene (11.8%) were also found to be present in high quantities. Whereas, 1,8-cineole (29.4%), γ-terpenene (11.6%), δ-cadinene (9.0%), β--pinene (6.9%) and α-thujene (6.3%) were the major components in the dry leaf oil. In the fresh flower oil, α-thujene (26.9%), T-muurolol (24.9%) δ–cadinene (13.1%) were the major components. The results reinforced the fact that there are quantitative and qualitative differences in the essential oil components of fresh and dry plant materials.

Leonotis leonurus

Mr Vice-Chancellor Sir, we also studied the effects of drying on the aerial part of *Leonotis leonurus* using three different drying methods. The herb is a popular garden plant commonly used by South African traditional healers to manage hypertension. The major compounds were reported to be cis & trans-β-ocimene (14.2-27.1%), β-pinene (14.7-16.4), germacrene D (10.4-12.9%) and caryophyllene oxide (5.3-9.0%) present in all of the oil samples. The monoterpenoids, although fewer in number than the sesquiterpenoids predominate in their oil content. Limonene was present in relevant quantities in oils from dried plant materials, but absent in the oil from fresh plant material. The introduction of menthone (3.5%) and pulegone (3.2%) in the oil of the oven-dried plant which possibly resulted from the oxidation of limonene or pinene was undesirable due to their

toxicity. The best oil yields were observed in the sun-dried plant parts. This yield almost doubled that of the oil from the fresh plant. The oil from the sun-dried plant was the best quality compared to those from the air and oven-dried plants. The research work found that the major components that defined the aroma and medicinal uses of the oil were all represented in high quantities (Asekun *et al.*, 2005).

Caesalpinia pulcherrima

Another study on the effects of the different drying methods on the yield and chemical composition of hydro distilled essential oil from the red variety of leaves of *Caesalpinia pulcherrima* was reported by Asekun *et al.* (2007). *Caesalpinia pulcherrima* is a species of flowering plant in the pea family, Fabaceae, it is native to the tropics and subtropics of the Americas. It could be native to the West Indies, but its exact origin is unknown due to widespread cultivation. Common names for this species include Poinciana, Peacock Flower, Red Bird of Paradise, Mexican Bird of Paradise, Dwarf Poinciana, Pride of Barbados and flamboyant-dejardi (Burkill, 1997). In Nigeria, it is commonly known as *Eko-omode* by the Yorubas, *Waken Bature* by the Hausas and *Nwayi/Nwoke Ibem* by the Igbos. The seeds of *Caesalpinia* species are poisonous at maturity but some are edible before they reach maturity (e.g. immature seeds of *C. pulcherrima*) or after treatment (Nelson, Shih, and Balick, 2007). In India, leaves of *C. pulcherrima* are traditionally used as purgative, tonic and antipyretic, while the root extracts are used in the treatments of convulsions. A total of 26, 23, 30 and 25 compounds were identified in the oils of the fresh, air-dried, sun-dried and oven-dried plant materials respectively. In general, the air-dried plant yielded more essential oils than the fresh, sun-dried and oven-dried plants. The air-dried, sun-dried and oven-dried plant materials yielded 0.90 %, 0.20 % and 0.58 % of the essential oils respectively whereas the fresh plant materials yielded oils of 0.63 %. The essential oils of *Caesalpinia pulcherrima* were composed mainly of sesquiterpenoids. The fresh leaf oil comprises caryophyllene, 15.51 %; α-cadinol, 14.36 %; γ–muurolene, 13.28 %; nerolidol, 8.32 % as the most prominent components. While the major

components common to the different drying methods were air-dried (phytol, 12.28 %; copaene, 9.07 %; γ-pyronene, 8.95 %; neryl propanoate, 6.55 %), sun-dried (neryl propanoate, 8.18 %; copaene, 5.49 %; phytol, 4.72 %; γ-pyronene, 0.87 %), oven-dried (copaene, 18.77 %; neryl propanoate, 7.61 %; γ-pyronene, 4.59 %; phytol, 3.25 %). Similar major compounds were present in all the dried leaf oils but at varying quantities, whereas, they all differ from the major compounds of the fresh leaf oil. This disparity may be due to the chemical transformation of the components in the different environments exposed to for moisture removal.

Table 11: Chemical composition of the essential oil from *Caesapinia pulcherrima* leaves using different drying methods

COMPOUND	Sun dried (%)	Oven dried (%)	Air dried (%)
Isopentyl hexanoate	1.19	-	0.83
Santolina triene	-	-	0.24
γ-pyronene	0.87	8.95	4.59
γ-Elemene	4.70	6.39	-
Coapaene	5.49	9.07	18.77
Calarene	3.64	0.69	-
α-muurolene	6.20	-	-
γ -muurolene	2.10	-	-
δ-cadinene	1.61	1.52	1.74
Cubebene	2.18	0.09	-
Valencene	0.45	-	-
α -calacorene	4.68	1.00	1.78
Ledane	-	-	0.25
γ-caryophyllene	-	-	3.15
Nerolidol	2.64	5.24	0.82
γ-Gurjunene	0.53	-	-
(+)-2-Carene, 4-.alpha.-isopropenyl-	-	-	2.03
α-cadinol	2.97	-	-
α-Himachalene	-	-	1.79
Aromadendrene	0.78	-	1.34
Bicyclo[5.3.0]decane,2-methylene-5-(1-methylvinyl)-8-methyl-	-	1.24	-

8-(2-Acetyloxiran-2-yl)-6,6-dimethylocta-3,4-dien-2-one.	-	2.44	4.10
β-selinene	1.44	-	-
β-caryophyllene	-	2.17	-
Caryophyllene	-	1.17	-
3-buten-2-ol, 2-methyl-4-(1,3,3-trimethyl-7-oxabicyclo[4.1.0]hept-2-yl)-	-	-	6.69
Caryophyllene oxide	2.33	6.54	-
Viridiflorol	2.99	-	7.42
Pinane	-	-	1.96
Farnesol (E), methyl ether	5.18	2.37	-
tricyclo[4.3.1.1.(3,8)undecane-3-carboxylic acid,methyl ester	-	-	3.25
Isoaromadendrene epoxide	3.70	2.23	-
Neryl propanoate	8.18	6.55	7.61
Aromadendrene oxide(2)	2.29	1.73	5.30
Aromadendrene(1)	-	-	4.80
1-Methyl-6-(3-methylbuta-1,3-dienyl)-7-oxabicyclo[4.1.0]heptane	4.21	-	3.89
Patchoulane	3.53	5.31	-
Cedrene epoxide	4.13	-	-
2-pentadecanone,6,10,14-trimethyl-	1.93	-	-
γ-neoclovene	-	2.85	-
(-)-Neoclovene-(I), dihydro	4.98	3.78	-
(-)-Isolongilofol methyi ether	-	1.31	-
Fenchol	-	3.81	-
Fenchone	4.82	-	-
Phytol	4.72	12.28	3.25
Acetic acid, 2-acetoxymethyl-1,2,3-trimethyl ester	-	1.19	-
(Z)6,(Z)9-Pentadecadien-1-ol	-	1.27	1.15
1,5-cyclodecadiene, (E,Z)-	0.56	-	-

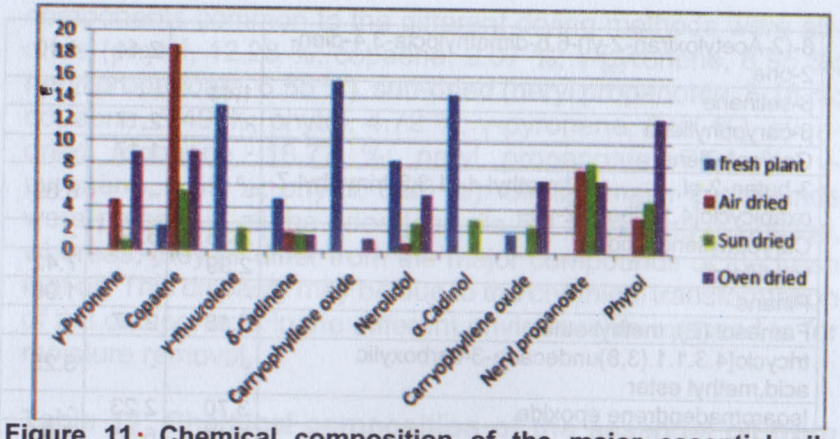


Figure 11: Chemical composition of the major essential oil components from *Caesalpinia pulcherrima* leaves using different drying methods

Curcuma longa

Curcuma longa is an Indian plant that belongs to the Zingiberaceae family (Burkill, 1985). It is commonly called turmeric and the yellow coloring principle extracted from the rhizomes is named Curcumin, this is responsible for the anti-inflammatory activities of the plant (Chopra, Gupta and Chopra, 1941). Turmeric is closely related to ginger and is used as a condiment. The plant has great importance in the food, textile and pharmaceutical industries. It has also been reported to have antioxidant, antiprotozoal, nematocidal, antibacterial, anti-HIV, and antitumor properties (Kiuchi *et al.,* 1993; Mazumber *et al.,* 1995; Polasa *et al.,* 1995).

The composition of the volatile oil from the rhizomes of *Curcuma longa* (turmeric) was investigated by means of gas chromatography – mass spectroscopy technique. Ten compounds were identified in the oil (98.56%). The essential oil components were mainly monoterpenoids of which the major components were α-phellandrene (37.16%), 1,8-cineole (34.29%), α-terpinolene (12.92%), α-pinene (4.51%) and gamma- terpinene (4.19%). The results presented in this study highlighted some features of the oil composition of *Curcuma longa* from Southwest, Nigeria and contributed to a better

knowledge of the turmeric from Nigeria. The contribution of the components of turmeric essential oil to the various medicinal and confectionery uses was also evaluated in brief in the study.

Table 12: Essential oil components of the rhizome of *Curcuma longa*

S/N	Oil Composition	% Composition	RI	Method of Identification
1.	α-Pinene	4.51	934	MS, RI
2.	b-Pinene	0.43	977	MS, RI
3.	Myrcene	2.37	996	MS, RI
4.	α-phellandrene	37.16	1008	MS, RI
5.	1.8-Cineole	34.29	1038	MS, RI
6.	g-Terpinene	4.19	1067	MS, RI
7.	α-Terpinolene	12.92	1079	MS, RI
8.	α-Terpineol	0.73	1178	MS, RI
9.	Terpinen-4-ol	1.25	1178	MS, RI
10.	p-Cymen-8-ol	0.29	1186	MS, RI

ESSENTIAL OIL - COMPOSITION AND BIOLOGICAL ACTIVITIES RESEARCH

Mr. Vice-Chancellor sir, this research journey also took me to the biological threshold of essential oils, where the activities of some medicinal plants were investigated. The essential oils were generally investigated for their antibacterial, antifungal, cytotoxicity, antioxidants and insecticidal activities. Essentially, the major components that determine the biological properties of the essential oil plants such as *Hyptis suaveolens* (L.). Poit, *Xylopia aethiopica, Abrus precatorius* (L), *Morinda lucida* (L.)

Benth, Pakia biglobosa (Jacq) Benth, *Delonix regia, Annona muricata* and *Cymbopogon citratus* were studied.

Studies on the Antimicrobial and Anticancer Activities of Essential Oils

Xylopia aethiopica

Xylopia aethiopica is commonly known as 'spice tree', 'Africa pepper', 'Ethiopian pepper' or 'Guinea pepper'. The fruits are reported to have high nutritive and medicinal value. In Nigeria, the fruits are used in cough medicines, as well as a carminative and stimulating additive to other medicines. The powdered root is employed as a dressing and in the local treatment of cancer.

The comprehensive analyses of the essential oil of fruits of *Xylopia aethiopica* (Annonaceae) were conducted. The gas chromatographic-mass spectrometric (GC-MS) analyses showed that the essential oil comprised mainly of monoterpenoids with 1,8-cineole (15.15%) being the most prominent compound. Sabinene (6.6%) and terpinen-4-ol (4.1%) were present in moderately significant amounts. The sesquiterpenoid contents identified were β -elemene (1.26%) and caryophyllene oxide (3.83%). The essential oil of fruits of *Xylopia aethiopica* showed good activity against four microorganisms and was cytotoxic to carcinoma cells (Hep-2 cell line) at 5 mg/ml concentration, which indicates its potential anticancer properties.

Figure 12: ***Xylopia aethiopica fruits and leaves***

Table 13: Chemical constituents of the essential oil of the fruit of *Xylopia aethiopica*

Peak numbers[a]	Compound	% Composition	MS Data[c]
8	p-Xylene	2.0	191,106,51,105,77
2	Octane	1.01	43,57,41,56,77
3	-Thujene	1.40	93,91,77,92,41
4	-Pinene	2.08	93,92,91,77,79
5	Sabinene	6.60	93,91,77,41,79
6	β-Pinene	2.25	93,41,69,79,77
7	-Phellandrene	0.64	93,77,136,79,41
8	Limonene	0.74	68,93,79,41,67
9	1,8-Cineole	15.54	43,71,81,55,41
10	α-Ionone	1.17	93,91,77,43,136
11	β-Ionone	2.44	93,43,91,77,91
12	Sabinol	1.51	91,43,92,41,81
13	Unidentified	1.87	91,119,41,43,67
14	Unidentified	1.57	53,108,81,41,107
15	Terpinen-4-ol	4.11	43,71,93,111,91
16	-Terpineol	2.70	59,43,93,121,67
17	Myrtenol	2.29	79,91,108,41,119
18	β-Elemene	1.26	93,81,67,41,68
19	Caryophylleneoxide	3.83	43,41,79,55,91
20	C H O	1.65	43,41,79,55,91
21	C H O	2.13	43,67,41,109,55
22	C H O	1.18	43,55,41,93,79
23	C H O	7.47	43,159,91,131,119
24	Elemol	0.47	59,43,41,105,93
25	C H O	0.57	43,91,41,55,79
26	C H O	0.81	159,43,91,41,105
27	C H O	0.31	43,133,145,91,105
28	C H O	0.44	43,44,41,55,93
29	C H O	0.21	43,91,79,41,147
30	Unidentified	0.27	81,43,55,41,91
31	Unidentified	0.13	41,55,123,43,81
32	Unidentified	3.19	43,55,81,67,41

[a]GC-MS peak numbers in eluting order; [b]Retention time on BPI capillary column (3.0m´0.25mmid) [c]Important peaks in decreasing order

Table 14: Antimicrobial activity of *X. aethiopica* essential oil

Microorganism	Inhibition zone (mm)			
Gram(q)bacteria	X.a.	Amp 9±0.3	Gen 12±0.3	TioNT
EscherichiacoliATCC25922	–			
Pseudomonasaeruginosa ATCC27853	–	–	10±0.2	NT
Gram(y)bacteria				
Staphylococcusaureus ATCC29213	–	10±0.2	16±0.3	NT
Fungi				
Stellocapella maydis	12±0.3	NT	NT	–
Candida albicans	–	NT	NT	18±0.2
Aspergillusflavus	10±0.5	NT	NT	16±0.3
A.ocheraceus	15±0.5	NT	NT	15±0.2
Fusariumoxysporum	10±0.3	NT	NT	12±0.5

Mean values (*n*=3)" ± S.D are given X.a.: *Xylopiaa ethiopica* (in 10% DMSO dilution) 5mg/ml; Amp:ampicillin 2.5 g/ml.
Gen: Gentamycin (1 g/ml); Tio: tioconazole 5 g/ml.
NT: not tested; - no inhibition.

Table 15: *In vitro* cell toxicity of the essential oil in the fruit of *X. aethiopica*

	LC50 µg/ml (methanol)	LC50 µg/ml (ethanol)
Brine shrimp	1.22±0.3	0.26±0.4
Hep-2Cells	0.045±0.3	0.036±0.3

Toxicity expressed as mean ± S.D., *n*=3

Hyptis suaveolens

Hyptis suaveolens (Bush Tea) (Labiatae) is a very popular remedy for fever and a number of diseases. The plant is locally called *Jogbo* in Yoruba speaking part of western Nigeria. The stem is reputed to possess anticancer properties and the leaves exert anti-fertility activities in women (Oliver-Bever, 1986). The plant is characterised by a strong mint-like odour. Analysis of the leaf essential oil afforded the identification of thirty-nine (39)

components with a dominant amount of sabinene (Asekun and Ekundayo, 2003). The sesquiterpenoid fraction comprised - caryophyllene and E- -bergamotene. The latter imparted a pleasant spicy odour on the oil which displays significant antimicrobial activities (Asekun *et al.* 1999). The essential oil of *H. suaveolens* showed antibacterial activity at 5 mg/ml concentration against two gram-positive and four gram-negative bacteria.

Table 16: Percentage composition of *Hyptis suaveolens* leaf oil

No.•	RI[1]	Constituents	Percentage	MS data•	Identification methods
	925	α-Thujene	0.6	93,77,41,136	MS,RI
2.	931	α -Pinene	2.3	93,77,41,121	MS,RI
3.	966	α -Sabinene	16.5	93,77,41,136	MS,RI
4.	968	β-Pinene	8.6	93,41,69,79	MS,RI
5.	984	Myrcene	0.2	41,93,69,77	MS,RI
6.	1002	α -Phellandrene	0.2	93,77,136,41	MS,RI
7	1007	α -3-carene	0.2	93,77,41,121	MS,RI
8.	1010	α -Terpinene	1.5	121.93.136.7	MS,RI
9.	1018	p-Cymene	0.9	119,91,134,7	MS,RI
10.	1021	Limonene	2.6	68,93,79,41	MS,RI
11.	1050	α -Terpinene	1.7	93,136,121,7	MS,RI
12.	1052	cis-Sabinene	1.0	43,71,93,81	MS,RI
13.	1078	Terpinoleneb	3.3	121,93,136,7	MS,RI
14.	1094	p-Mentha-4(8)-dieneb	0.6	93,121,136,7	MS,RI
15.	1100	Linalool	0.4	71,43,93,55	MS,RI
16.	1120	α -Fenchol	0.4	81,41,69,55	MS,RI
17.	1159	Terpinen-4-ol	9.6	71,111,93,43	MS,RI
18.	1171	Methylsalicylate	0.3	120,92,39,71	MS,RI
19.		α -Terpineol	0.3	59,93,43,81	MS,RI
20.	1392	P-Elemene	0.1	81,93,69,79	MS,RI
21.	1405	P-Caryophyllene+		41,93,69,79	MS,RI
22.		trans- α -Bergamotene	19.6	93,119,41,69	MS,RI

23.	1438	(E)-P-Famesene	1.4	69,41,93,79	MS,RI
24.	1479	α -Humulene	1.0	93,80,121,41	MS,RI
25.	1479	α -Selinene	1.7	93,105,41,79	MS,RI
26.	1551	Bicyclogermacrene	1.6	121,93,107,79	MS,RI
27.	1555	Lsocaryophyllene oxide	4.5	41,79,93,103	MS,RI
28.	1579	Spathulenol	1.9	43,91,79,119	MS,RI
29.	1586	Caryophyllene oxide	0.4	41,79,93,69	MS,RI
30.	1608	Humulene epoxide[s]	0.3	43,67,109,96	MS,RI
31.	1613	T-Cadinol	0.2	161,43,105,204	MS,RI
32.	1625	11-Selinen-4-ol	0.9	43,81,71,95	MS,RI
33.	1672	trans- α -Bergamotol	0.3	93,41,119,79	MS,RI
34.	1676	trans- α -Bergamotol acetate	1.9	93,119,41,55	MS,RI
35.	1962	Isopimar-9(11)-15-diene	0.2	257,41,105,91	MS,RI
36.	2018	Rimuene	1.2	257,272,149,91	MS,RI
37	2152	Beyerene	0.4	91,69,135,105	MS,RI
38	2150	(Neo) Abietol	0.2	135,41,148,91	MS,RI
39	2309	Abietadiene	0.3	41,105,273,91	MS,RI

Table 17: Antimicrobial activity of the essential oil of *Hyptis suaveolens* leaves

Microorganisms	Inhibitionzone[a]mm.			
	E.o.	Amp	Gen	Tio
Gram-positive				
Staphylococcus aureus UCH560	-	R	14	n.t
*S. aureus*UCH681	-	-	10	n.t.
*S. aureus*UCH511	14	R	12	n.t.
Bacillus cereus	10	-	14	n.t.
*E. coli*UCH307		12	12	14
*E. coli*UCH270		10	-	-
Pseudomonasa eruginosa NCTC6750	-	9	10	n.t.
*P. aeruginosa*UCH655	14	-	-	n.t.
Fungus				
Candida albicans	16	n.t.	n.t.	16

[a]Values are the mean of three replicates. Abbreviations. E.o: essentialoil in 10% DMSO dilution: 5mg/ml; Amp: ampicillin 2.5µg/ml, Gen: gentamycin 1µg/ml; Tio:tioconazole 5µg/ml; R:resistant; n.t.: not tested;-:no inhibition; NCTC: NationalCollectionTypeCultures; UCH: Clinical isolates, University of Ibadan, College Hospital Collection

Antioxidant Activity of Essential Oils

Plant decoctions, herbs, spices, infusions, and poultices which are known to be rich in secondary metabolites have been used for years in the management of diseases. Phytochemical studies have shown that secondary metabolites including essential oils (EOs) exhibit strong antioxidant activity. In recent times, the use of antioxidants has drastically reduced the prevalence of oxidative stress-related diseases (OSD). Antioxidants are compounds that can quench or mop-up free radicals and prevent them from causing cell damage. They cause protective effect by neutralising or inhibiting free radicals, which are toxic by-products of natural cell metabolism. Enzymatic endogenous antioxidants including catalase, superoxide dismutase, glutathione peroxidase attempt to rid oxidants in a physiological process, however, the constellation of radicals generated including lipid peroxyl (LP•), superoxide (O_2•), nitric oxide (NO•), hydroxyl (HO•), consequent to metabolic activities and environmentally induced stress factors, overwhelms the naturally produced antioxidants.

Essential oils can serve as credible alternatives to synthetic antioxidants due to their potentials to diffuse microorganism cell membrane resulting in the inhibition of cell growth as well as the capacity to scavenge free radicals. I report below some essential oil plants, their compositions and antioxidant activities.

Abrus precatorius

Abrus precatorius belongs to Leguminosae (Fabaceae) family, commonly called crab's eye, Rosary pea, Blackeyed Susan, Precatory bean or India liqurice. In southwest Nigeria (Yoruba) it is called *Ojuologbo, Otobere* in Southeast Nigeria (Igbo) and *Idonzakara* in northern Nigeria. It is indigenously found throughout India, even at altitudes up to 1200 m on the outer Himalayas. It is now naturalized in all tropical countries (Burkill, 1985). We evaluated the composition and antioxidant capacity of the seed and shell essential oils of *Abrus precatorius* (L). The GC/MS analyses indicated the presence of 33 and 27 constituents in the seed and shell oil representing 91.41 and 85.85 % of total oil respectively. Zingiberene was identified in

both oils, it is a popular composition of ginger and a good anti-inflammatory agent. It protects against stomach ulcers, ease the pain and discomfort caused by stomach gas and arthritis. The ability of the oils to act as hydrogen/electrons donor or scavenger of radicals was determined by *in-vitro* antioxidant assays established protocols. The IC_{50} values of the seed and shell oils (2.10 mg/mL and 1.20 mg/mL respectively) had activity higher than that for rutin (3.40 mg/mL) for the nitric oxide scavenging assay. The lipid peroxidation radical activity of the oils was similar to vitamin C, weak DPPH and ABTS radical scavenging activities were discovered in comparison to vitamin C and rutin. Generally, in the four antioxidant assays, a significant correlation existed between concentrations of the oils and percentage inhibition of free radicals and lipid peroxidation.

Figure 13: Picture of *Abrus precatorius* plant https://troop75.typepad.com/photos/common_poisonous_plants_o/black-eyed-susan-crab-eye-abrus-precatorius-seeds-2.html

Table 18: Compounds isolated from *Abrus precatorius* essential oil and their applications

Classes of Compounds	(%) Major compounds isolated		Relevance of compound in management of diseases
	Seed essential oil	Shell essential oil	
Monoterpenoids	Limonene (19.08) Borneol (4.32) Terpineol (2.34)	Sabinene (10.93), Myrcene (8.04) Camphene (6.45) Borneol (2.82) Terpineol (1.27),	Cancer cells inhibitor (Joung &Anton, 2010) Skin and anti-inflammatory diseases (Valente *et al.*, 2013) Anticardiovascular disease agent (Ioanna *et al.*, 2011)
Sesquiterpenoids	Zingiberene (6.02) Sesquiphelladrene (4.47)	Zingiberene (10.75)	-
Unsaturated fatty acids	-	10-Octadecenoicacid (14.08) Hexadecanoic acid (5.58)	Antioxidant, and antiinflammatory (Cockbain *et al.*, 2013)

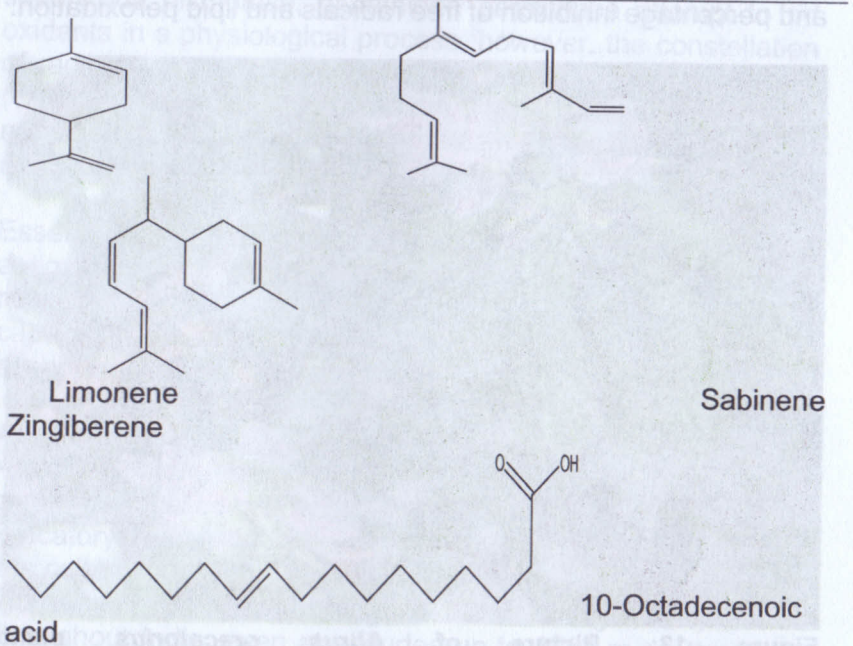


Figure 14: Structures of major compounds isolated from *Abrus precatorius* essential oil (*Okoh, Asekun et al. 2013*)

Table 19: Antioxidant capacity of essential oils of *Abrus precatorius* (mg/mL)

S/N	Activity	*Abrus precatorius*		Standard/Commercial (Positive Controls)		Antioxidants
		Seed Oil(IC_{50})	Shell Oil (IC_{50})	Vitamin C (IC_{50})	Rutin (IC_{50})	BHT[b] (IC_{50})
1.	DPPH·	5.0 3± 0.24	3.03 ± 0.11	1.50 ± 0.01	0.50 ± 0.04	ND
2.	ABTS·+	2.95 ± 0.31	3.07 ± 0.22	0.10 ± 0.04	0.10 ± 0.01	ND
3.	LP·	1.92 ± 2.10	1.42 ± 0.40	1.83 ± 0.33	ND	0.83 ± 0.40
4.	NO·	2.10 ± 0.40	1.20 ± 0.20	1.20 ± 0.20	3.40 ± 0.01	ND

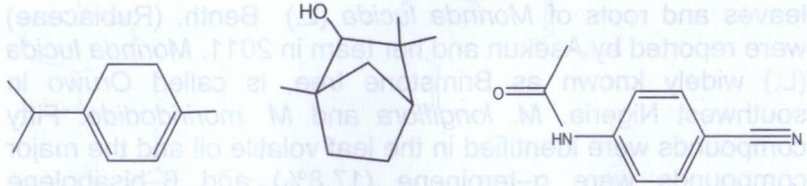
DPPH· =2,2-diphenylpicrylhydrazyl radicals, ABTS·+ =2,2′-azino-bis diammonium salt radicals,
LP· = lipid peroxide radical, NO· = Nitric oxide radical, [b]BHT =Butylated hydroxyl toluene, ND = Not determined, the lower IC_{50} (mg/mL) the higher the antioxidant capacity. Values are mean ± SD, *n*=3.

Morinda lucida

In another study, the composition and antioxidant activity of leaves and roots of *Morinda lucida* (L.) Benth. (Rubiaceae) were reported by Asekun and her team in 2011. *Morinda lucida* (L.) widely known as Brimstone tree, is called *Oruwo* in southwest Nigeria. *M. longiflora* and *M .morindodide*. Fifty compounds were identified in the leaf volatile oil and the major compounds were α–terpinene (17.8%) and β–bisabolene (16.3%). In the root oil, 18 compounds were identified, the major constituents being 3-fluoro-*p*-anidine (51.8%) and hexadecanoic acid (12.0%). Antioxidant activities of the oils were examined using the DPPH, ABTS reducing power and lipid peroxidation assays. All assays were concentration dependent with varying antioxidant potentials. The antioxidant activity of the root volatile oil of *M. lucida* was similar to that of the standard drugs used. It is also interesting to note that the oils possess lipid peroxidation inhibitory activity. This study shows that besides the traditional uses of the plant mentioned, the volatile oils extracted from *M. lucida* leaves and root have good antioxidant potential and can be used to produce natural antioxidants as well as natural food preservatives.

Table 20: Chemical composition of essential oils isolated from *Morinda lucida*

Classes of Compounds	(%) Major compounds isolated		Relevance of compound in management of diseases
	Leaf essential oil	Root essential oil	
Monoterpenoids	α-Terpinene (17.90) Fenchyl alcohol (7.95)	-	
Sesquiterpenoids	β-Bergamotene (16.30) α-Bergamotene (14.02)	Carvacrol (3.79)	Antioxidant, antihypertensive, antiasthmatic (Edris, 2007).
Non-terpenoid	-	4-cyano-N-acetyl aniline (51.78)	Anticancer, antiinflammatory, neuroprotective (Garella, *et al.*,2013; Rescifina *et al.*, 2014).



α-Terpinene Fenchyl alcohol 4-cyano-N-acetyl aniline

Figure 13: Structures of major compounds isolated from *M. lucida* essential oil

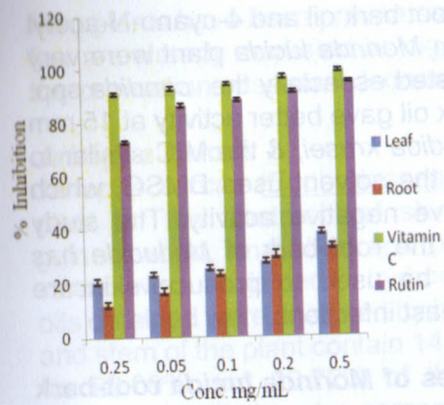


Figure 15a: Antioxidant effect of the volatile oils from the leaves and root of M. lucida by using ABTS.

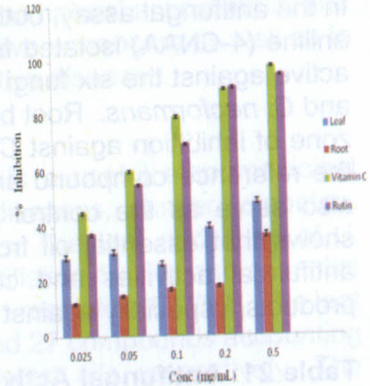


Figure 15b: Antioxidant effect of the volatile oils Of M. lucida by using DPPH.

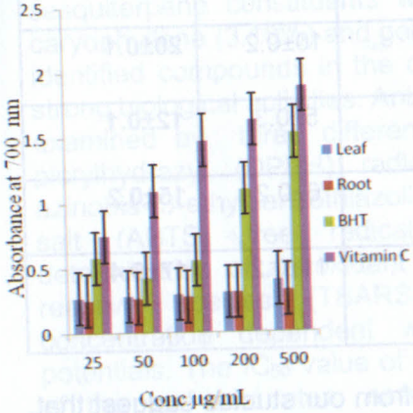


Figure 15c: Antioxidant effect of the volatile oils from the leaves and root of M. lucida by using lipid peroxidation.

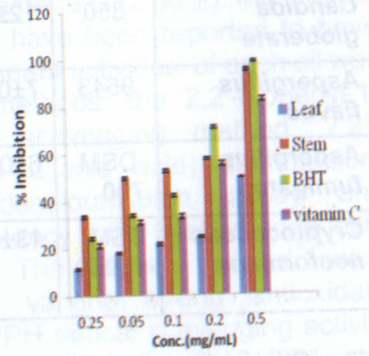


Figure 15d: Antioxidant effect of the volatile oils from the of M. lucid using lipid peroxidation leaves and root of M. lucida by using reducing power free radical.

In the antifungal assay, both root bark oil and 4-cyano-N-acetyl aniline (4-CNAA) isolated from *Morinda lucida* plant were very active against the six fungi tested especially the *candida* spp. and *C. neoformans.* Root bark oil gave better activity at 15 mm zone of inhibition against *Candida krusei, &* the MIC similar to the reference compound and the solvent used DMSO, which also serve as the control gave negative activity. The study shows that essential oil from the root bark of *M. lucida has* antifungal activities and can be used to produce skincare products, especially against yeast infections.

Table 21: Antifungal Activities of *Morinda lucida* root-bark & CNAA

Test Fungi	ATCC	*M. lucida* Oil (Inhibition)		Amphotericin B
		Root bark	CNAA	
Candida albican	2091	**13±0.2**	11±0.1	**17±0.1**
Candida krusei		**14±0.2**	10±0.1	**15±0.3**
Candida globerate	350	**12±0.1**	10±0.2	**20±0.1**
Aspergillus flavus	9643	7±0.1	5±0.3	**12±0.1**
Aspergillus fumigatus	DSM 790	6±0.3	6±0.2	**15±0.2**
Cryptococcus neoformans	DSM 11959	**13**±0.4	11±0.2	**17±0.4**

Vice-Chancellor sir, the findings from our studies suggest that, supporting the traditional uses of the plant extracts, essential oils have strong bioactive compounds with noteworthy antimicrobial and antioxidant properties and may be good candidates in the search for lead compounds for the synthesis of novel potent antibiotics and anticancer agents. Essential oils

from plants have been proven safe as natural antioxidants, and few are already marketed as digestive enhancers as well as in the prevention of several degenerative diseases.

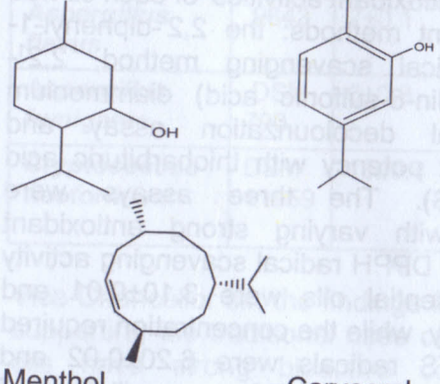
Jatropha curcas

Jatropha curcas (Euphorbiaceae) is a useful ethnomedicinal plant for the treatment of skin diseases, cancer, diabetes, guinea worm, snakebite and piles. The leaf and stem of *J. curcas* were subjected to hydrodistillation for 3hr and essential oils obtained were analysed by high-resolution GC/MS. The leaf and stem of the plant contain 14 and 27 compounds accounting for 89.09% and 90.72% of the total oils respectively. The GC/MS identified twelve components in the leaf oil. The major sesquiterpenoids in the leaf oil were γ- cadinene (14.46%) and germacrene D (10.87%), α-aromadendrene 8.32%, caryophyllene oxide 7.95%, while the principal monoterpenoid components were menthol (11.50%), β-citral (11.14%), limonene (6.20%) and α-pinene (5.69%). Twenty-five compounds were identified in the stem essential oil. The dominant monoterpene compounds in the stem oil were β - terpinene (10.59%) and α-pinene (3.52%) while the major sesquiterpene constituents were γ- cadinene (5.49%), β – caryophyllene (3.18%) and germacrene D (2.30%). Most of the identified compounds in the oils have been reported to have strong biological activities. Antioxidant activities of each oil was examined by three different methods: the 2,2'-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging method, 2,2[1]-azinobis-(3-ethylbenzothiazolin-6-sulfonic acid) diammonium salt (ABTS) free radical decolourization assay and determination of antioxidant potency with thiobarbituric acid reactive species (TBARS). The three assays were concentration dependent with varying strong antioxidant potentials. The IC_{50} value of DPPH radical scavenging activity of the leaf and stem essential oils were 3.10±0.01 and 8.80±0.03 mg/ml respectively, while the concentration required for 50% inhibition of ABTS radicals were 6.20±0.02 and 4.6±0.02mg/ml respectively. In the TBARS assay, dilutions of the two oils were examined for their ability to act as hydroxyl (OH) radical scavenging agents using egg-yolk homogenate as

lipid rich media. Both volatile oils exhibited moderate antioxidant effect. The leaf and stem oils could inhibit 50% lipid damage by 11.50mg/ml and 9.50mg/ml respectively. The antioxidant activities of the two oils are significantly different ($P < 0.05$) compared to standard drugs (BHT and Vitamin C) we used in this study.

Table 22: Chemical composition of essential oils isolated from *Jatropha curcas*

Identified Compounds (%)	**87.24**	**87.77**
Aliphatics hydrocarbon (alkanes, alkene, aldehyde)	-	41.83
Monoterpenes	13.88	16.33
Oxygenated monoterpenes	24.44	-
Sesquiterpenes	38.03	14.88
Oxygenated sesquiterpenes	10.89	13.32
Carboxylic acid	-	0.49



Menthol Carvacrol Citral
Germacrene D

Figure 16: Structures of major compounds isolated from *J. curcas* essential oil

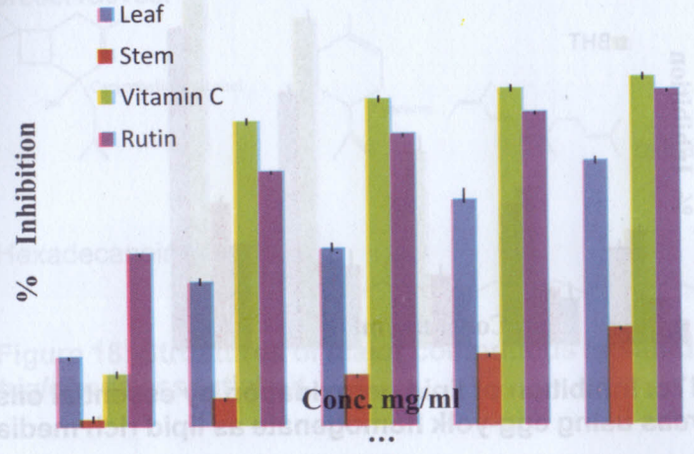


Figure17a: *J.curcas* oils antioxidant activity against

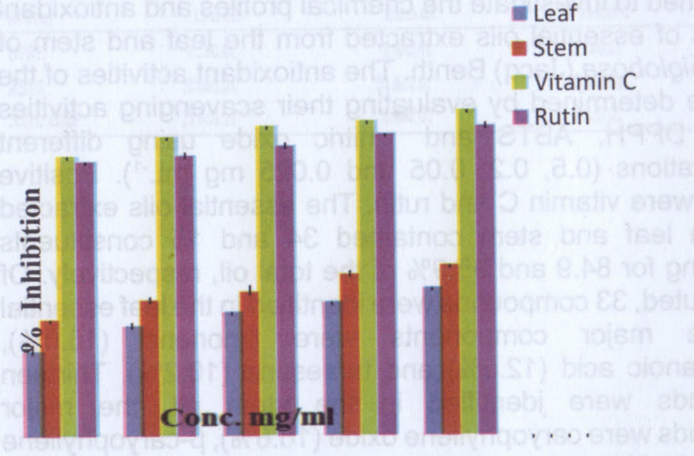


Figure 17b: *J.curcas* oils scavenging activity of ABTS radicals

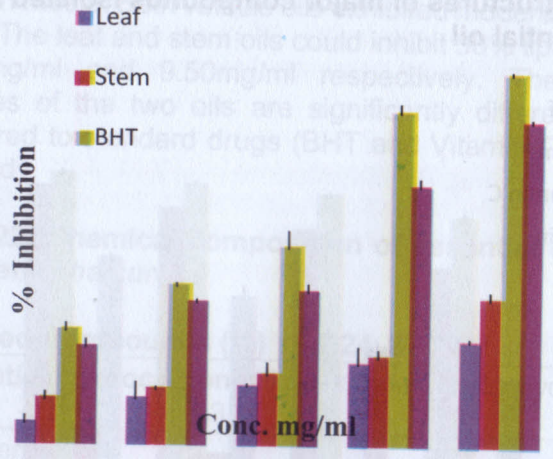
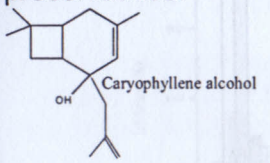


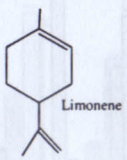
Figure 17c: Inhibition of lipid peroxidation by essential oils of *J. curcas* using egg-yolk homogenate as lipid rich media

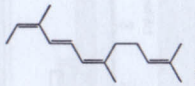
Parkia biglobosa

A similar study was conducted on *Parkia biglobosa* (Jacq) Benth which is our popular locust beans, iru, in Nigeria. This study aimed to investigate the chemical profiles and antioxidant activities of essential oils extracted from the leaf and stem of *Parkial biglobosa* (Jacq) Benth. The antioxidant activities of the oils were determined by evaluating their scavenging activities against DPPH, ABTS and nitric oxide using different concentrations (0.5, 0.2, 0.05 and 0.025 mg mL^{-1}). Positive controls were vitamin C and rutin. The essential oils extracted from the leaf and stem contained 34 and 15 constituents accounting for 84.9 and 95.9% of the total oil, respectively. Of the 34 eluted, 33 compounds were identified in the leaf essential oil. The major components were limonene (16.0%), hexadecanoic acid (12.5%) and farnesene (10.2%). Thirteen compounds were identified in the stem oil, the major compounds were caryophyllene oxide (16.6%), β-caryophyllene alcohol (14.9%), terpinene-4-ol (12.1%) and β-caryophyllene (8.1%). The three antioxidant assays were concentration dependent with varying antioxidant potentials. The antioxidant activity of the leaf and stem oils were similar to that of the standard drugs used. The present findings suggest that the

essential oils obtained from the leaf and stem of *P. biglobosa* possess a strong antioxidant potential and can be used to produce natural antioxidants as well as natural food preservatives.







Hexadecanoic acid

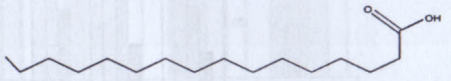


Figure 18: Structures of major compounds isolated from *P. biglobosa* essential oil

Table 23: Antioxidant activities of essential oils of *P. biglobosa*. IC_{50} (mg mL^{-1})

Activity	Leaf oil	Stem oil	Vitamin C	Rutin
DPPH	4.2±0.01	5.8±0.03	1.5±0.01	0.5±0.04
ABTS	10.8±0.01	24.6±0.01	0.1±0.04	0.1±0.10
Nitric oxide	25.6±0.11	8.8±0.02	8.2±0.02	8.4±0.01

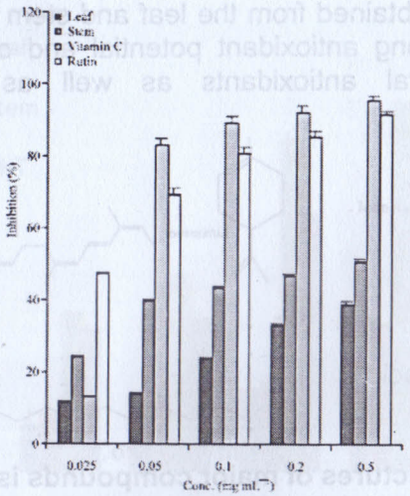


Figure 19a: Antioxidant effect of the essential oils extracted from P. biglobosa on DPPH radicals

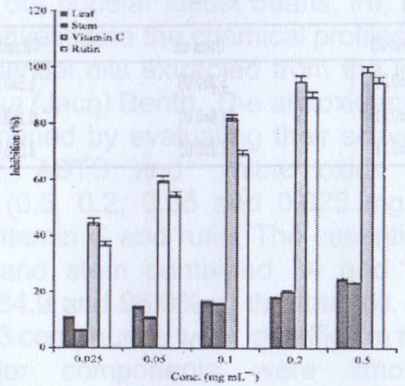


Figure 19b: Antioxidant effect of the extracted from P. biglobosa on ABTS free radicals

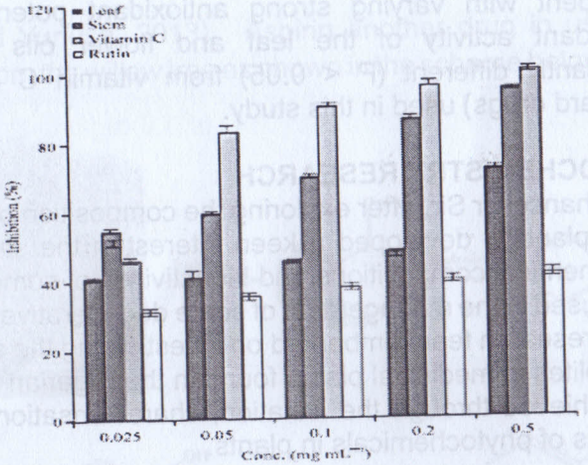


Fig. 19c: Antioxidant effect of the essential oils extracted from P. biglobosa on nitric oxides radicals

Cassia/ Senna alata

Cassia Sennaalata (Leguiminoseae) commonly called ringworm bush or candlestick is widely distributed in tropical countries and is used for the treatment of ringworm, diarrhoea, cholera, eczema, itching and scabies in Nigeria. The leaves and flowers were subjected to hydrodistillation and essential oils obtained analysed by high-resolution GC/MS. The essential oils extracted from the leaf and flower contained 23 and 25 constituents accounting for 94.31 and 96.30 % respectively. The major sesquiterpenes constituents identified in the leaf oil were azulene (10.30%), caryophyllene (10.30 %), germacrene D (10.20 %), while citral (11.40 %), limonene (7.30 %), linalool (5.7 %) and camphene (5.6 %) were the prominent monoterpenes found in the leaf oil. The dominant constituents identified by the GC/MS in the flower oil were azulene (13.80 %), hexadecanoic acid (13.77 %), 2-methyl naphthalene (12.01 %) and α- Ionone (7.30 %). The antioxidant activities of the oils were examined by evaluating their radical scavenging activities against DPPH, ABTS and nitric oxide radicals. The results of these assays showed that the oils were concentration

dependent with varying strong antioxidant potentials. The antioxidant activity of the leaf and flower oils were not significantly different ($P < 0.05$) from vitamin C and Rutin (standard drugs) used in this study.

PHYTOCHEMISTRY RESEARCH

Vice-Chancellor Sir, after exploring the composition of essential oils in plants, I developed a keen interest in the study of the phytochemical compositions and bioactivities of some Nigerian plants used in the management of some degenerative diseases. So my research team embarked on investigating the secondary metabolites in medicinal plants found in the Nigerian flora. This was achieved through the isolation, characterisation and bio-activities of phytochemicals in plants.

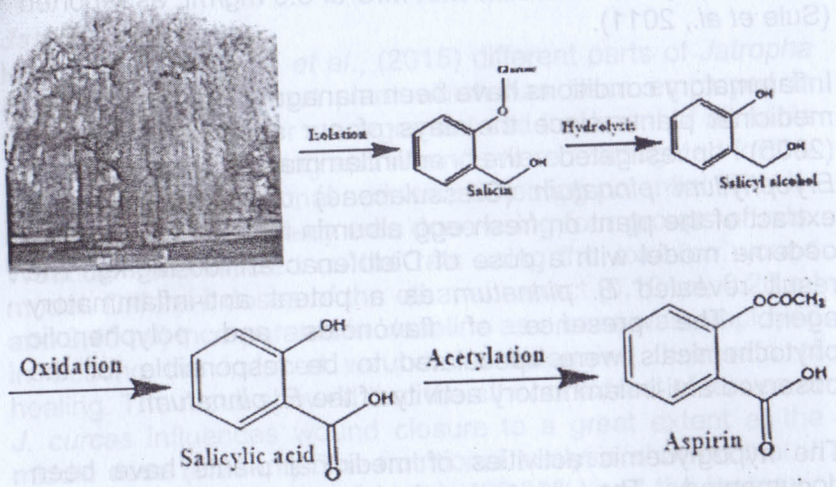
Phytochemicals as Alternative Therapeutic Agent

Man from time immemorial has depended on medicinal plants as a source of primary health care. These plants are made up of chemical components called phytochemicals which are responsible for their exhibited therapeutic or toxicological potentials or those that synthesize metabolites to produce useful drugs (WHO, 2008). Phytochemistry is the study of chemicals in plants, particularly alkaloids, glycosides, polyphenols and terpenoids.

Medicinal Plants as Source of Drug Discovery

The isolation of bioactive compounds from medicinal plants has been a potent medium employed in new drug discovery. About 50% of the drugs in clinical use originated from natural products and their derivatives. They are an essential foundation of chemical agents, drug leads and new drugs which are indispensable in this era of increase in drug resistance pathogens (Cragg *et al.,* 2014; Ahvazi *et al.,* 2012). It was estimated that in 2001, one-quarter of the top selling medicines globally were either natural products or came from them (Butler, 2004). The bark of *Cinchona* is the source of malaria- attacking quinine. Opium was reported to be a source of codeine, morphine and paregoric used in the treatment of diarrhoea, while morphine, till date, is an acceptable pain relief medication

(Lawal and Yunusa, 2013). Aspirin another drug in use was obtained from the willow tree as shown in the scheme below.



Scheme 1: Isolation of Aspirin from Willow Plant

Medicinal Plants as Potential Therapeutic Agents

Some medicinal plants have been studied and scientifically validated as potential therapeutic agents as used in Folk medicine. The potent antimicrobial activities of the gel and leaf of *Aloe vera* against a wide range of bacteria and fungi were reported by Vishaalini *et al.,* (2016) and Irshad *et al.,*(2011). Bearberry and cranberry juice have been used to treat urinary infections while plant species such as lemon balm, garlic and tea tree were reported as broad-spectrum antimicrobial agents (Sandasi *et al.,* 2010). Some plant extracts such as methanol extract of *Emblica officinalis* (Amla) have been reported to be comparable with Ciprofloxacin drug against *Escherichia coli* (gram negative bacterial) and *Bacillus subtillis* (gram positive bacterial) respectively.

As an antifungal, plants' extracts such as ethanol extract of leaves and stem bark extract of *Senna alata* Linn (Fabaceae)

was reported to exhibit potent antifungal activities on dermatophytes namely: *Microsporum canslaslomyces, Trichophyton verrucosum, Trichophyton mentagrophytes, and Epidermophyton floccosum* with MIC of 5.0 mg/mL as reported (Sule *et al.*, 2011).

Inflammatory conditions have been managed and treated using medicinal plants since the days of our ancestors. Ojowole, (2005) investigated the antiinflammatory potential of *Bryophyllum pinnatum* (Crassulaceae) using aqueous leaf extract of the plant on fresh egg albumin-induced pedal (paw) oedema model with a dose of Diclofenac at 100 mg/kg. The result revealed *B. pinnatum* as a potent anti-inflammatory agent. The presence of flavonoids and polyphenolic phytochemicals were speculated to be responsible for the observed anti-inflammatory activity of the *B. pinnatum.*

The hypoglycemic activities of medicinal plants have been documented. The phytochemicals such as glycosides, alkaloids, terpenoids, flavonoids, carotenoids and tannins are frequently implicated as having antidiabetic potentials. The oral administration of aqueous extract of *C. ensiformis* seeds has been reported to reduce urinary, blood glucose levels, in addition to raising the levels of triacylglycerol, ketone bodies and cholesterol connected with diabetes mellitus (Nimenibo-Uadia, 2003). The effect of extract of *C. ensiformis* seeds on hyperlipidemia and hyperketonemia in alloxan-induced diabetic rats established it as an active antidiabetic herb (Malviya *et al.*, 2010).

CONTRIBUTIONS TO PHYTOCHEMISTRY RESEARCH

The phytochemistry, nutrient, proximate analysis and isolation of bioactive compounds from some Nigerian plants were investigated. These plants include: *Jatropha curcas, Hibiscus rosa-sinensis, Brassica oleracea capitata* var *Alba, Acalypha godseffiana* and *Bridelia ferruginea.*

The results obtained from the phytochemical composition of the plants along with some of their pharmacological activities are summarised below.

Jatropha curcas

In a study by Asekun *et al.*, (2015) different parts of *Jatropha curcas,* the physics nut plant which has been employed in traditional medicine for management and treatment of ailments such as vaginal bleeding and wounds were investigated for the phytochemical, nutritional and wound healing potential. The *in-vivo* wound healing study was done using four groups of rats. Wounds were inflicted on the rats using the excision wound model. Different doses of the ethanol extract (0.10 ml, 0.20 ml and 0.40 ml) incorporated in Vaseline as a base was employed in treating the induced wounds to determine their rate of healing. The result showed that the ethanol extract of leaves of *J. curcas* influences wound closure to a great extent at the middle dose (0.20 ml). The nutritional analysis showed that *J. curcas* is a good source of protein (62.30%) and the inorganic content was revealed in total ash content of 14.4%. Phytochemical screening of the ethanolic crude extract revealed the presence of alkaloids, flavonoids, tannins, phenols, steroids and terpenoids. The mineral composition indicated the leaves of *J. curcas* as a potential source of inorganic elements such as magnesium (92.38 mg/100g), manganese (9.04 mg/100 g), zinc (3.10 mg/100g) and Copper (0.78 mg/100g). The result of this study demonstrated a significant wound healing activity of ethanolic extract of the leaves of *J. curcas*, established its traditional claim as a wound healing plant. *J. curcas* could be a potent wound healing candidate for use in future.

Table 24: Effects of ethanol extract of *J. curcas* leaves in the excision wound model

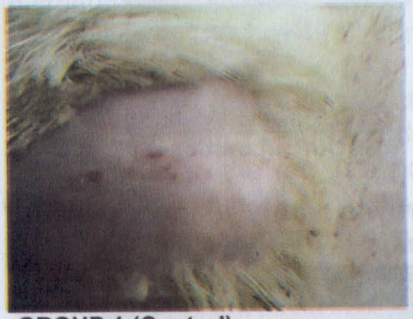
Treatments	Wound Contraction (%)						
	Day 2	Day 4	Day 6	Day 8	Day 10	Day 12	Day 14
Control (Vaseline)	-15.0 ± 0.14	3.5 ± 0.05	13.5 ± 0.21	38.5 ± 0.21	45.0 ± 0.29	58.5 ± 0.21	66.5 ± 0.31
Low Dose (0.1 ml)	-11.5 ± 0.13[a]	1.5 ± 0.13[b]	15.0 ± 0.08[a]	48.0 ± 0.21[a]	64.0 ± 0.19[a]	66.0 ± 0.17[a]	70.0 ± 0.22[a]
Middle Dose (0.20 ml)	15.0 ± 0.08[a]	26.5 ± 0.05[a]	53.5 ± 0.09[a]	72.0 ± 0.25[a]	81.5 ± 0.13[a]	93.5 ± 0.05[a]	95.0 ± 0.12[a]
High Dose (0.40 ml)	8.5 ± 0.13[a]	16.5 ± 0.05[a]	40.0 ± 0.08[a]	58.5 ± 0.09[a]	73.5 ± 0.09[a]	83.5 ± 0.05[a]	83.5 ± 0.05[a]

Values are mean ± SD (n= 3). [a]Significant increase vs. control ($p<0.0001$); [b]Significant decrease vs. control ($p<0.0001$) (2-way ANOVA with Dunnett's multiple comparisons test using GraphPad Prism 6 software).

Hibiscus rosa-sinensis

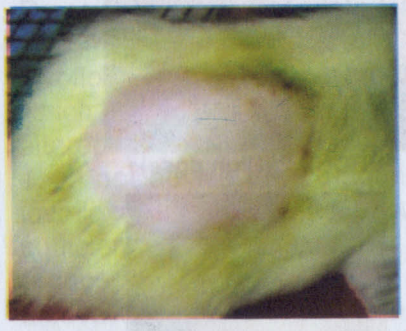
Hair growth promoting agents are in high demand because of the psychosocial effects of alopecia on human especially cancer patients undergoing chemotherapy. Plants have been employed since ancient times in traditional medicine for hair growth promotion. In this study, the leaf of *Hibiscus rosa-sinensis* a common herb in Nigeria acclaimed traditionally for hair growth-promoting potential was studied. The ethanolic extract of the leaves of *H. rosa-sinensis* was subjected to phytochemical screening using standard methods already adopted. The proximate compositions were determined by the official methods of analysis and the hair growth investigation of the ethanolic extract was carried out using established protocols at concentrations of 2.5 mg/ml, 5 mg/ml and 10 mg/ml. Four groups of albino rats were used. The results of the phytochemical screening revealed the presence of alkaloids, flavonoids, tannins, phenols, steroids and terpenoids. The proximate analysis showed that the leaves have high protein

(48.57%) content, carbohydrate, ash, moisture, fibre and lipids were also present in descending order. The micro and macro-nutrients were determined to be magnesium (91.52 mg/100g), sodium (20.40 mg/100g), iron (12.31 mg/100g), potassium (9.70 mg/100g), manganese (8.90 mg/100g), calcium (7.57 mg/100g), zinc (4.80 mg/100g), and copper (0.23 mg/100g). Complete hair regrowth was observed after a 21-day treatment with the 5 mg/ml concentration of the leaf ethanolic extract, petroleum jelly was the control. The result of this study suggests that the leaf of *Hibiscus rosa-sinensis* has hair growth and probably hair loss prevention potentials.

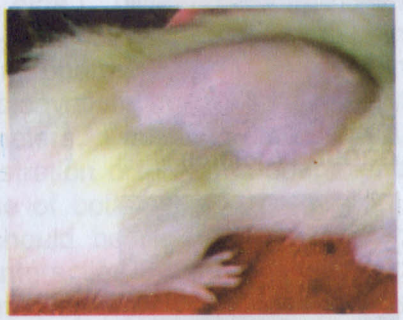


GROUP 1 (Control)

GROUP 2 (High dose)



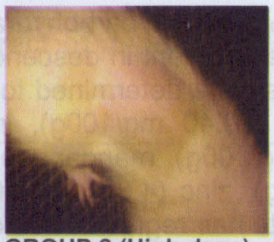
GROUP 3(Middle dose)



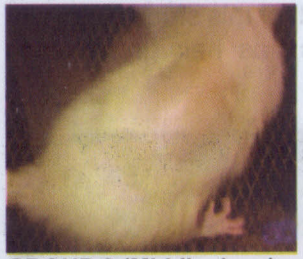
GROUP 4 (Low dose)

Figure 20a: Day 1 and 2 of hair growth study using the extract of leaves of *Hibiscus rosa-sinensis*

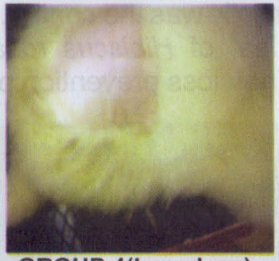
GROUP 1 (Control)



GROUP 2 (High dose)

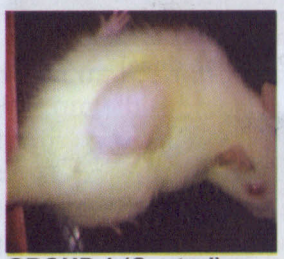


GROUP 3 (Middle dose)

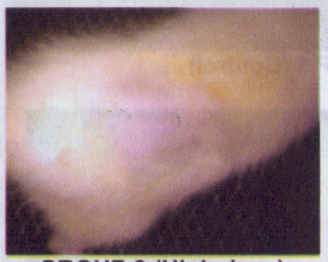


GROUP 4(Low dose)

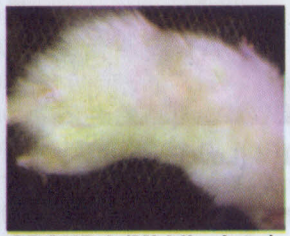
Figure 20b: Day 6 of hair growth study using extract of leaves of *Hibiscus rosa-sinensis*



GROUP 1 (Control)



GROUP 2 (High dose)



GROUP 3 (Middle dose)

GROUP 4 (Low dose)

Figure 20c: Day 21 of hair growth study using extract of leaves of *Hibiscus rosa-sinensis*

Brassica oleracea capitata* var *Alba

The significance of the interaction between Levofloxacin and *Brassica oleracea capitata* var *Alba* L. (Green Cabbage), a commonly eaten vegetable in Nigeria was evaluated in this study. The pharmacokinetic parameters of Levofloxacin administered orally to cabbage pre-treated male albino Wister rats were established. Blood samples from the rats were collected over 48h for the quantification of Levofloxacin using HPLC. The presence of green cabbage extract significantly caused a 1.3-fold increase in the $AUC_{0-\infty}$ of Levofloxacin (285.15 to 359.81) but a 3.6-fold decrease in V_d, volume of distribution (1.53 to 0.43) and a two-fold decrease in F, bioavailability (90.2 to 49.5). Findings from the study suggested that co-administration of green cabbage with Levofloxacin may result in antagonistic interactions causing negative clinical implications with decreased distribution and bioavailability of Levofloxacin in the rat. The nutrients of green cabbage were also discovered to be Zn, Mn, Fe, Cu, Cr, Ca, K, Mg and Na using the atomic absorption spectroscopic analysis. Alkaloids, glycosides, saponins, flavonoids, steroids, terpenoids, phenols, amino acids, carbohydrates and tannins were found to be in varying degrees. Findings from this study indicated that *Brassica oleracea capitata* Var *Alba* L. (Green Cabbage) is a high mineral content herb. Co-administration of the herb with levofloxacin exhibited significant pharmacokinetic interaction which resulted in decreased bioavailability of the drug and altered pharmacokinetic parameters. This study, therefore, does not advice the co-administration of green cabbage and levofloxacin but should the use of both agents be required, sufficient time, (about 3hrs) should be allowed between to reduce the possibility of interaction, hence increasing bioavailability and ensure the efficacy of Levofloxacin which is the inhibition of DNA replication by entering the bacterium via passive diffusion.

Table 25: Pharmacokinetic parameter estimates of oral levofloxacin (7.14 mg/kg) with and without concomitant oral administration of green cabbage crude extract (30 mg/kg)

Pharmacokinetic Parameters	Levofloxacin Only (Control) Group	Levofloxacin + Extract Group
C_{max} (µg/ml)	7.62	15.0
T_{max} (h)	2.6	12.8
Cl_r	94.9	41.2
MCR	0.01	0.04
F (%)	90.2	49.5
V_d (ml/kg)	1.53	0.43
$AUC_{0\rightarrow\infty}$ (µg/ml/hr.)	285	359
$T_{1/2}$ ab (h)	2.75	4.40
$T_{1/2}$ el (h)	11.2	7.2
K_{abs} (h^{-1})	0.25	0.16
K_{el} (h^{-1})	0.06	0.10

Bridelia ferruginea

Bridelia ferruginea (Euphorbiaceae) commonly found in Savannah regions, is usually a gnarled shrub which sometimes reaches the size of a tree. This plant in Southern Nigeria is considered sacred and is featured in certain rituals and ceremonies. It is used as ethnomedicine for the treatment of various ailments in many parts of Africa. (Cimanga *et al.* 1999; Okwu and Ukanwa 2010; Mbah *et al.* 2012). Based on traditional medicinal uses, previously reported activities and our crude extract which showed moderate activity towards the CB2 receptor and potent against leishmanial pathogen, we were encouraged to study the cannabinoid, opioid receptors and antileishmanial activities for the compounds isolated from *B. ferruginea* Phytochemical investigation of the methanolic extract of dried leaves of *Bridelia ferruginea* led to the isolation and identification of fourteen compounds (**1**–**14**): compound **1** [mixture of palmitic,stearic and oleic acids], stearyl monoester of 2-*O*-*β*-D-glucosylglycerol(**2**), 6*β*-hydroxy-(20*R*)-24-ethylcholest-4-en-3-one (**3a**), 6*β*-hydroxy-(20*R*)-24-ethylcholest-4,22-dien-3-one (**3b**), lutein (**4**), vomifoliol(**5**), corilagin (**6**), kaempferide-3-*O*-*β*-D-glucoside (**7**), myricetin (**8**),

isomericitrin (**9**), isoquercetin (**10**), myricitrin (**11**), quercitrin (**12**), rutin (**13**), and *β*-sitosterol glucoside (**14**). The total extract exhibited moderate activity towards CB2 receptor and 90% inhibition against leishmanial pathogen *Trypanosoma brucei*. Compound **4 (Lutein)** exhibited 73% displacement in CB2 receptor with IC_{50} 56.47 µM, and 93% inhibition towards *T. brucei* with IC_{50} 4.16 µM. Compound **11** (Myricitrin) showed 99% inhibition towards *Escherichia coli* with IC50 1.123 µM. The methanolic extract of dried leaves of *B. ferruginea* showed 90% activity towards *T. brucei* and moderate activity (48% displacement) towards CB2 receptor. Compounds **2–7**, **9**, and **12** were reported for the first time from this plant (Afolayan 2019).

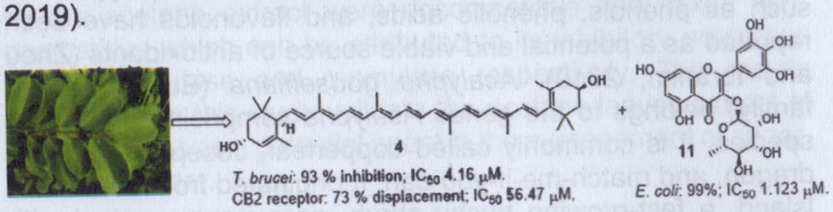


Figure 21: Bioactive compounds 4 and 11 from *B. ferruginea*

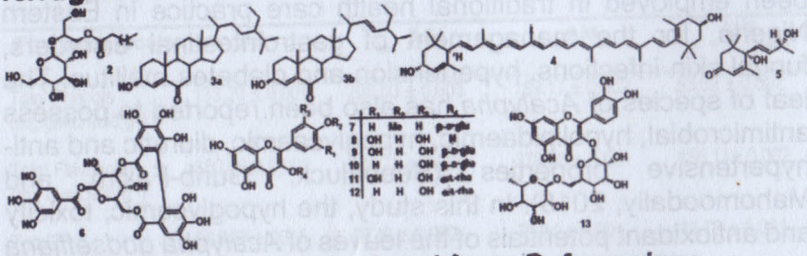


Figure 22: Compounds isolated from *B. ferruginea*

Acalypha godseffiana

Non-communicable diseases such as diabetes mellitus are among the five leading causes of death in the world (Joseph and Jini, 2011). In sub-Sahara regions of Africa such as Nigeria and South Africa, it was reported by the World Health Organization that the burden of diabetic epidemic of all age groups in Africa was approximately 7.1 million at the end of 2000, and estimated to increase by 2030 to 18.6 million (Shaw,

Sicree and Zimmet, 2010). Worse still, Nigeria and South Africa are at a higher risk in Africa, with an incidence rate of 4.50% and 8.30% respectively (Joseph and Jini, 2011). Diabetes mellitus (DM) is a chronic metabolic disease described by high blood sugar consequential from an inability of the body to produce insulin or utilise the insulin produced, or both. DM pandemic is associated with unhealthy lifestyle, civilization, ageing and effects of reactive oxygen species (ROS). If uncontrolled, DM results in serious long term complications such as cardiovascular disease, stroke, chronic kidney failure, foot ulcers, and damage to the eyes which eventually causes deaths of sufferers (Levitt, 2008). Plants polyphenols such as phenols, phenolic acids, and flavonoids have been reported as a potential and viable source of antioxidants (Zhou and Ibrahim, 2010). *Acalypha godseffiana* (Euphorbiaceae family) belongs to the genus *Acalypha* comprising about 570 species. It is commonly called copperleaf, Joseph's coat, fire dragon, and match-me-if-you-can. It originated from the Pacific Island, a fast-growing bushy shrub, an evergreen plant with green leaf blade and creamy-white margins. The expressed juice or boiled decoction of the leaves of *A. godseffiana* has been employed in traditional health care practice in Eastern Nigeria, for the management of gastrointestinal disorders, fungal skin infections, hypertension and diabetes mellitus. The leaf of species of *Acalypha* has also been reported to possess antimicrobial, hypolipidaemic, hypoglycaemic, diuretic and anti-hypertensive properties (Seebaluck, Gurib-Fakim and Mahomoodally, 2015). In this study, the hypoglycemic, toxicity and antioxidant potentials of the leaves of *Acalypha godseffiana* were investigated with respect to acetone, ethanol, methanol and aqueous extracts. The study was also able to link the hypoglycemic activity extracts of leaves of *A. godseffiana* to their polyphenolic contents. The phytochemical compositions and antioxidant potentials of acetone, aqueous, ethanol and methanol extracts of *A. godseffiana* were determined using adopted methods. An *in-vitro* approach was used to evaluate the hypoglycemic potentials of the extracts on α-amylase and α-glucosidase enzymes. The mechanism of inhibitions was studied using the Lineweaver- Burk plot. Antioxidant results

revealed that total antioxidant capacity of the acetone extract (IC_{50}: 0.34 mg/mL) showed better activity compared to the standards (silymarin 0.52 mg/mL; gallic acid 0.51 mg/mL). The hypoglycemic findings confirmed that acetone extract demonstrated strong and mild inhibitory potential against α-amylase and α-glucosidase respectively, showing concentration dependence with IC_{50}values of 2.33 mg/mL and 0.13 mg/mL. The observed hypoglycemic and antioxidant potentials of acetone extract of *A. godseffiana* correlate to its high polyphenolic contents which include phenols (133.20 mg gallic acid g-1), flavonoid (350.60 mg quercetin g-1) and tannins (264.67 mg catechin g-1). The mechanisms of action exhibited by the acetone extract were uncompetitive and mixed non-competitive which can be attributed to its inhibitory properties on α-glucosidase and α-amylase respectively. The results obtained from this study validate the acetone leaves extract of *A. godseffiana* as a potential agent in the management of sugar-related disorder.

Table 26: Total Phenolic Composition of Extracts of *A. godseffiana* (leaves)

Phytochemicals	AA	AE	AM	AW
Total Phenols (mg gallic acid g-1)	133.20 ± 0.001	208.03 ± 0.003	189.17 ± 0.002	53.52 ± 0.002
Total Flavonoid (mg quercetin g^{-1})	350.60 ± 0.002	304.25 ± 0.001	379.66 ± 0.001	156.11± 0.002
Total Proanthocyanidin (mg catechin g^{-1})	264.67 ± 0015	45.09 ± 0.002	75.84 ± 0.001	13.73 ± 0.001

***Key: AA=** Acetone extract; **AE=** Ethanol Extract; **AM=** Methanol extract; **AW=** Water Extract

Table 27: IC_{50} (mg/mL) of ***A. godseffiana*** (leaves) in different anti-oxidative models

Assay	SLY	GAL	ACE	ETE	MEE	AQE
DPPH	0.47 ± 0.01^{a}	1.90 ± 0.03^{b}	0.66 ± 0.03^{c}	0.51 ± 0.02^{a}	0.64 ± 0.05^{a}	0.69 ± 0.01^{c}
FRAP	0.33 ± 0.03^{a}	1.00 ± 0.05^{b}	3.79 ± 0.01^{c}	3.92 ± 0.01^{d}	2.25 ± 0.03^{e}	5.38 ± 0.02^{f}
TOC	0.52 ± 0.01^{a}	0.51 ± 0.03^{a}	0.34 ± 0.01^{b}	0.37 ± 0.04^{b}	0.59 ± 0.02^{c}	0.41 ± 0.05^{d}
MCH	3.01 ± 0.01^{a}	1.21 ± 0.05^{b}	0.68 ± 0.02^{c}	2.18 ± 0.05^{d}	0.56 ± 0.01^{e}	0.51 ± 0.02^{e}
ABTS	0.42 ± 0.01^{a}	0.97 ± 0.03^{b}	0.60 ± 0.01^{c}	0.43 ± 0.05^{a}	0.50 ± 0.02^{d}	0.58 ± 0.02^{c}

***Key:** Each value of IC_{50} obtained by linear regression equation is presented as mean ± SEM (where n=3); Values with different superscripts in the same row for each parameter are significant ($p<0.05$) to each other. **DPPH:** 1, 1-Diphenyl-2-picrylhydrazyl; **TOC:** total antioxidant capacity by phosphomolybdenum; **FRAP**: ferric reducing ability of plasma; MCH: metal chelating ability; **ABTS:** 2, 2-azinobis-(3-ethylbenzothiazoline-6-sulphonate) radical cation; **OH:** hydroxyl radical scavenging capacity. **SLY=** Silymarine; **GAL=** Gallic acid; **AA=** Acetone extract; **AE=** Ethanol Extract; **AM=** Methanol extract; **AW=** Water Extract

TABLE 4: IC_{50} values of α-amylase and α-glucosidase inhibition by *Acalypha godseffiana* (leaves) extracts.

Sample	α-Amylase	α-Glucosidase
Acarbose	0.71 ± 0.02^{a}	1.28 ± 0.04^{a}
Acetone extract	2.33 ± 0.01^{b}	0.13 ± 0.01^{b}
Ethanol extract	3.97 ± 0.01^{c}	0.31 ± 0.05^{c}
Methanol extract	1.52 ± 0.04^{d}	0.50 ± 0.04^{d}
Water extract	2.85 ± 0.03^{e}	0.30 ± 0.02^{e}

Note: Each value of IC_{50} obtained by linear regression equation is presented as mean ± SEM (where $n = 3$). Values with different superscripts in the same column for each parameter are significant ($p < 0.05$) to each other.

ORGANIC SYNTHESIS RESEARCH CONTRIBUTIONS

Mr. Vice-Chancellor Sir, in 2012, my interest in the synthesis of bioactive compounds sprung as a result of the research collaboration initiated between the University of Lagos and the University of Soochow in China. I was among the four lecturers invited by Soochow University for a research visit in honour of the Scholars Exchange Programme between the two Universities. I did my research at the Organic Chemistry laboratory, College of Material Science and Chemical Engineering. I joined the research team of Prof Jian-Ping Zou, the team worked mainly on the synthesis of organic compounds based on selective radical addition to the unsaturated system.

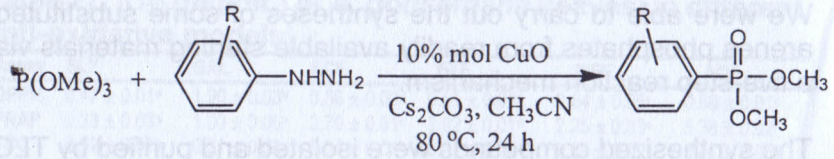
We were able to carry out the syntheses of some substituted arenes phosphates from readily available starting materials via a five-step reaction mechanism.

The synthesized compounds were isolated and purified by TLC and flash column chromatography. The characterisation of the isolated compounds was carried out using the LC-MS, HNMR and CNMR analysis. The importance of these compounds in synthetic, agrochemical and medicinal chemistry has been well documented throughout the years.

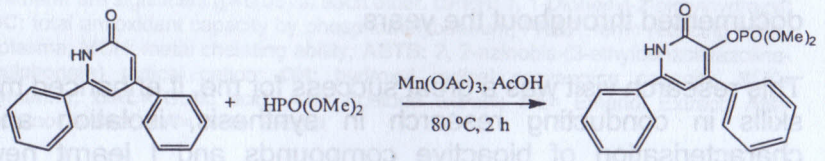
This research visit was a great success for me, it enhanced my skills in conducting research in synthesis, isolation and characterisation of bioactive compounds and I learnt new techniques which enabled me develop and gain expertise in the area of organic synthesis, LC-MS and HNMR & CNMR. The results of the findings are summarised below.

Copper-Catalyzed Cross Coupling Reactions of Arylhydrazines and Trialkylphosphites

New methods for the synthesis of arylphosphonates were developed by us. Prior to this time, the Michaelis–Arbuzov reaction was a well-known method for C–P bond formation; however, it was not applicable to the formation of aryl C–P bonds (Hirao *et al.*, 1981). This work is particularly interesting because phosphonylated aza heterocycles are associated with many biologically active compounds that are important in organic, medicinal and agricultural chemistry but these reactions require multistep synthesis following reported procedures. The team added to the body of knowledge by reporting the first examples of the synthesis of arylphosphonates via CuO catalysed reaction (Scheme 1) and via manganese (III) acetate mediated selective free radical phosphonylation reaction (Scheme 2). These methodologies provide a novel, simple and cost-effective protocol for the preparation of arylphosphonates.



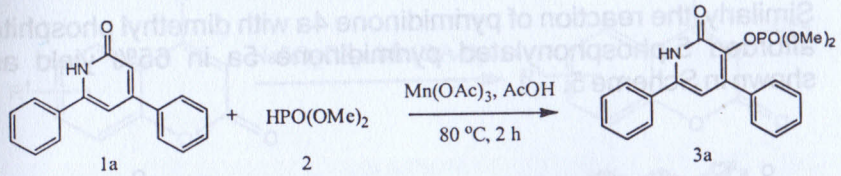
Scheme 1: Copper-catalyzed coupling reaction of arylhydrazines and trialkylphosphites



Scheme 2: Phosphonylation of 4,6-diphenylpyridin-2(1H)-one

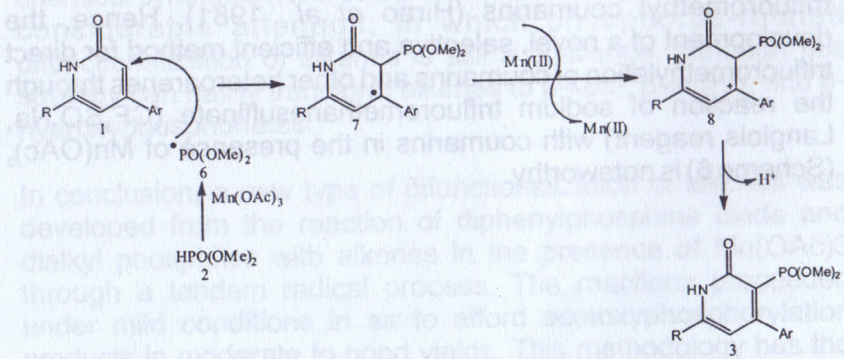
Mn(OAc) 3-Mediated Selective Free Radical Phosphonylation of Pyridinones and Pyrimidinones

The Chinese team and my humble self also presented methods for the synthesis of pyrimidinylphosphonates, with examples of manganese (III) acetate promoted direct phosphonation of pyridinones and pyrimidinones with a diakyl phosphite. The team developed a manganese (III)-mediated regioselective phosphonation reaction of pyridinones and pyrimidinones. This work is particularly interesting because phosphonylated azaheterocycles such as pyridinones and pyrimidinones are associated with many biologically active compounds which are important in organic, medicinal and agricultural chemistry but these reactions require multistep synthesis following reported procedures (Maruyama and Honjo. 1988), however, with the method reported herein, the reactions are straightforward and efficient. In order to develop reaction condition, 4,6-Diphenylpyridin-2(1H)-one (**1a**) was used as a substrate, the synthesis afforded phosphonylated product **3a** in 72% yield. (Scheme 3).



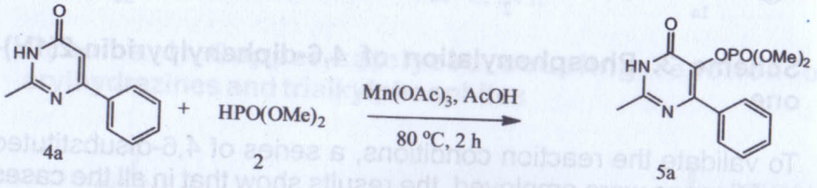
Scheme 3: Phosphonylation of 4,6-diphenylpyridin-2(1H)-one

To validate the reaction conditions, a series of 4,6-disubstituted pyridinones were employed, the results show that in all the cases 3-phosphonylated pyridinones were produced in moderate to good yields and no 5-phosphonylated pyridinones or phenyl phosphonylated products were observed, it was also noted that aromatic substituents at the 4- and 6- positions of the pyridinone have no significant effect on the product yield. The proposed mechanism for the phosphonylation of pyridinones is illustrated in scheme 2 where electrophilic phosphonyl radical **6** generated from the reaction of manganese (III) acetate with dimethyl phosphite attacks the 3-position of pyridinones **1** to form radical **7**, largely because this position has higher electron density than other sites. Radical **7** is oxidized by the second equivalent of manganese (III) acetate to form carbocation **8** followed by the deprotonation of **8** to give product **3**.



Scheme 4: Proposed mechanism for phosphonylation of pyridinones

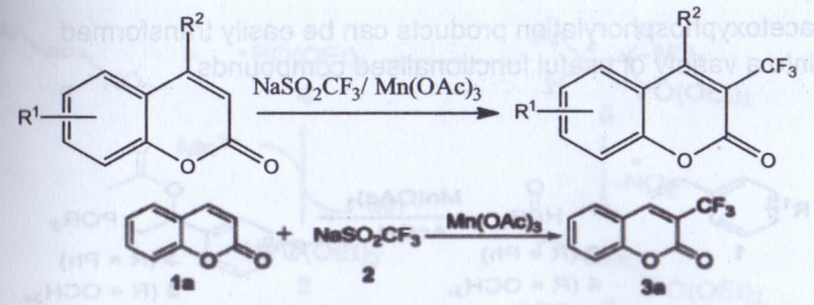
Similarly, the reaction of pyrimidinone 4a with dimethyl phosphite afforded 5-phosphonylated pyrimidinone 5a in 65% yield as shown in Scheme 5.



Scheme 5: Phosphonylation of pyridiminone

Manganese (III)-mediated direct C sp2–H radical trifluoromethylation of coumarins with sodium Trifluoromethanesulfinate

Another contribution to knowledge in the synthetic world by the Chinese team and us was in the synthesis of coumarins. Coumarins are significant natural products that display wide and interesting pharmacological properties such as antibreast cancer, antiHIV, antiAlzheimer, vasorelaxant and platelet antiaggregatory activities. However, in coumarin derivatives, 3-trifluoromethyl coumarins were not as easily accessible as 4-trifluoromethyl coumarins (Hirao *et al.*, 1981). Hence, the development of a novel, selective and efficient method for direct trifluoromethylation of coumarins and other heteroarenes through the reaction of sodium trifluoromethanesulfinate (CF_3SO_2Na, Langlois reagent) with coumarins in the presence of $Mn(OAc)_3$ (Scheme 6) is noteworthy.



Scheme 6: Trifluoromethylation of coumarins

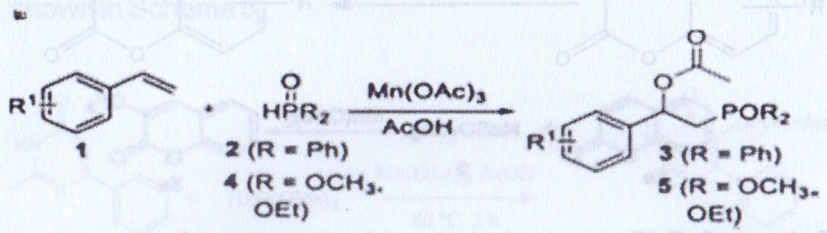
This methodology is straightforward and provides a general, effective and cheap way for the synthesis of 3-trifluoromethyl coumarins and other trifluoromethylated heteroarenes such as 3-trifluoromethyl quinolinone-2 and 5-trifluoromethyl pyrimidinones.

Direct radical acetoxyphosphorylation of styrenes mediated by Manganese (III)

Direct radical acetoxyphosphorylation of styrenes mediated by Mn(OAc)3 with diphenylphosphine oxide and dialkyl phosphites were described in this study, and a new type of difunctionalization of alkenes was achieved. Direct difunctionalization of alkenes is one of the most powerful transformations known in the field of chemical synthesis (Kolb *et al.*, 1994), so it has gained increasing considerable attention, in which phosphorus-related difunctionalization of alkenes is still a challenge, although this strategy can easily transform alkenes to β-keto, β-amino, and β-hydroxyphosphonates.

In conclusion, a new type of difunctionalization of alkenes was developed from the reaction of diphenylphosphine oxide and dialkyl phosphites with alkenes in the presence of Mn(OAc)3 through a tandem radical process. The reactions proceeded under mild conditions in air to afford acetoxyphosphorylation products in moderate to good yields. This methodology has the advantages of being straightforward, no need of additives and other oxidants, short reaction time, simple manipulations, and the

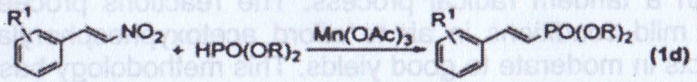
acetoxyphosphorylation products can be easily transformed into a variety of useful functionalised compounds.



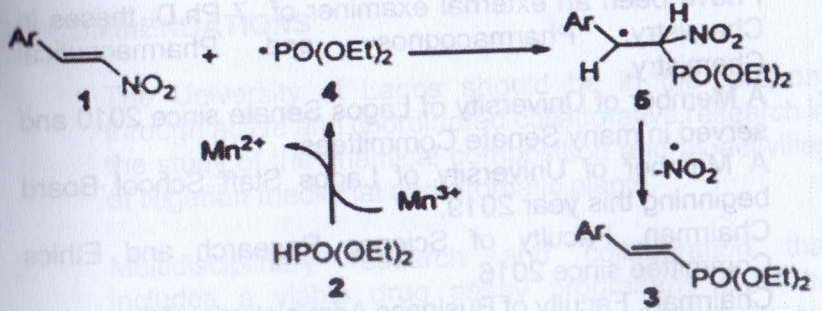
Scheme 7: Reactions of Alkenes 1 and Diphenylphosphine Oxide 2 with Dialkyl Phosphites

Manganese(III)-mediated alkenyl Csp2–P bond formation from the reaction of β-nitrostyrenes with dialkyl phosphites

Carbon–phosphorus bond formation is a topic of current interest in organic chemistry, in which alkenyl Csp2–P bond formation has attracted much attention. There are two main strategies applicable in forming the alkenyl Csp2–P bond: the phosphorylation of (1) alkynes and (2) functionalised alkenes. Nitroalkenes are an important class of organic compounds; they are readily available and participate in diverse reactions. In conclusion, a new approach for alkenyl Csp2–P bond formation was developed from the Mn(OAc)3-mediated reaction of phosphonyl radicals with β-nitrostyrenes through a tandem radical addition–denitration process. The reaction proceeded under mild conditions in air to afford the selective (E)-alkenyl phosphonates in moderate to good yields. This methodology provides a novel, simple and cost-effective protocol for the preparation of alkenyl phosphonates.



Scheme 8: Strategies for alkenyl Csp2–P bond formation



Scheme 9: Proposed mechanism for the reaction of β-nitrostyrenes (1) with diethyl phosphite (2).

CONCLUSION

I have in the last hour informed this distinguished audience what Phytochemistry is all about and how nature created by God has endowed us with abundant naturally occurring chemicals as food, drugs, medicines and pesticides including all through my modest contributions in the last 2 decades. Of particular mention, is the identification of some biologically active compounds from the plants and the importance of essential oils to mankind. They are powerful agents for change, they can help physically, emotionally, spiritually and financially. It is pertinent to affirm that the key to a successful drug discovery programme is a viable biological assay system. Collaboration across many disciplines is thus desirable and provision of adequate facilities is crucial. Research in this area is becoming more and more expensive with newer technologies that are not presently available in Nigeria.

ADMINISTRATIVE & ACADEMIC ACTIVITIES WITHIN THE UNIVERSITY

Vice-Chancellor Sir, aside from my research contributions to knowlegde, I have also served the University of Lagos in various ways listed below:

- I have been an external examiner of 7 Ph.D. theses in Chemistry, Pharmacognosy and Pharmaceutical Chemistry.
- A Member of University of Lagos Senate since 2010 and served in many Senate Committees.
- A Member of University of Lagos Staff School Board beginning this year 2019.
- Chairman, Faculty of Science Research and Ethics Committee since 2016.
- Chairman, Faculty of Business Administration Misconduct Panel since 2016.
- I was Acting Head of Chemistry Department from August 2014 to July 2016.
- I was Hall Mistress, Erastus Akingbola PG Hall of residence from November 2011 to November 2017.
- A Member of SPGS Academic Planning Committee from 2011 to December 2017.
- I was a Member, School of Postgraduate Studies Board from 2009 to December 2017.
- I was a Member, Student's Welfare Board from May 2011 to November 2017.
- I was also the Hall warden, Erastus Akingbola PG hall of residence from 2010 to 2011.
- The Chairman, Department of Chemistry Postgraduate Committee, August 2009 to August 2014.
- A Member of SPGS Student welfare Committee from 2009 to 2011.
- A Member of Center for Information Technology & Systems (CITS) Management Board from June 2008 to August 2014.
- The Chemistry Department Seminar Coordinator from 2008 to 2011.
- A Member of Faculty of Science Committee on Review of Future Needs (Unilag) 2007-2011.
- The Course Adviser for 6 years, 2003/2004 session to 2008/2009 session.

RECOMMENDATIONS

1. The University of Lagos should be in the forefront through active and coordinated collaborative research in the study of the chemical composition and bioactivities of Nigerian medicinal and aromatic plants.

2. Multidisciplinary research and collaboration that includes a viable drug assay programme must be strongly encouraged if we must get value from our abundant medicinal plants

3. Quality research in phytochemistry should be funded by the Government through the University because of the need to systematically search for leads to new drugs and medicinal constituents and even food condiments, pesticides and other agricultural needs.

4. Massive cultivation of some aromatic plants should be embarked upon nationally due to the immense benefits that can be derived from these plants. Our campus can serve as the pilot bed for this initiative; this will enhance a healthier environment and accessibility to these plants.

5. The University should encourage private participation by industries in quality research and development collaborations.

6. The Federal Government through the Federal Ministry of Science & Technology should increase support to the Nigerian Institute of Traditional Medicine for the Institute to play the desired mandate and role for the nation.

7. The University is called upon to endorse and appropriately fund the preparation of a compendium of Nigerian Aromatic and Medicinal Plants.

8. The University should make arrangements for the provision of state of the art scientific equipment especially the acquisition of a Nuclear Magnetic Resonance (NMR) instrument as a priority because this instrument is key to any meaningful organic chemistry research and it is also very valuable for multidisciplinary research in almost all areas of science and engineering.

9. Post-Doctoral Grade should be established in Nigerian Universities, starting from our great institution, the University of Lagos.

ACKNOWLEDGEMENTS

Mr. Vice-Chancellor, Sir, I would like to sincerely express my gratitude to all those who have made me who I am today. First, the Almighty God, who has not just made me who I am today but also made this Inaugural lecture possible. To Him be all glory and adoration!

I remember with deep appreciation, the love and care I received from my parents, who are now of blessed memory. I owe all I am today to my late parents. They valued education so much and ensured myself and my siblings had a quality education. I also thank them both for our upbringing and the realisation that education is paramount to our well-being. May God continue to keep you both in His bosom.

I thank the Management of University of Lagos, the University of First Choice under the leadership of our erudite Vice-Chancellor, Prof. Oluwatoyin Ogundipe and his team, Professor Oluwole Familoni (DVC Academic and Research), Professor Ben Oghojafor (DVC Management Services), Prof. Folashade Ogunsola (DVC Development), and other members of the management team of the University of Lagos.

I want to appreciate the immediate past Vice-Chancellor, Professor Rahman Ade Bello under whose tenure I got my Professorial Chair. Our dear Vice-Chancellor of blessed

memory Adetokunbo Sofoluwe, I thank him for ensuring I got an apartment on campus when I needed it most, may God grant you perfect peace.

I thank in particular, distinguished Prof. Babajide Alo and Prof. Familoni, both in Organic Chemistry. They are my academic mentors who contributed a lot to my career focus and progression, thank you for the support given to me in all of my accomplishments, both of you inspire me a lot because you are down to earth, very focused in your thinking and very encouraging of those who work with you. You have endowed the spirit of team work within our department and I have learnt a lot from both of you as good leaders.

I am grateful to my immediate past Supervisor, Professor Olusegun Ekundayo under whose guidance I learnt the rudiments of scientific research. I appreciate Prof. Anthony Afolayan at the University of Fort Hare, Republic of South Africa, for my Postdoctoral experience.

My gratitude also goes to my alma maters, the University of Ibadan and Ogun State University now Olabisi Onabanjo University where I was nurtured. I learnt integrity, responsibility and hard work from my secondary school principals, teachers and classmates at Remo Divisional High School, Sagamu. I am also grateful to the Lagos State University where I started my career as a lecturer and the University of Lagos where my career was capped. God bless you all.

I thank Emeritus Prof. Ogunlesi, Profs Olayinka, Okiei, Ayejuyo and Adams for the special interest they have in my well-being and career improvement. All my other colleagues in the Department of Chemistry, I thank you for your individual roles which made a significant impact in my academic life. God bless you all.

With great appreciation, I thank Prof. H.A.B. Coker, Retired Distinguished Prof. Abass and Prof. Chendo, My Dean, Prof. Adekunle, Professors Makanjuola, Otubanjo, Okpuzor, Ugoji,

Kemi Odukoya for their wonderful roles in my life. May God bless you bountifully. I also thank all academic and non-academic members of the Faculty of Science. I must say that I have enjoyed being part of the Faculty of Science family. God bless you all. I am also grateful to all members of the University of Lagos Community that I have interacted with, especially members of the Committees I have worked with in various capacities.

It is appropriate at this juncture to acknowledge the various supports through the provision of research grants and travel fellowships I received from the University of Lagos, I am most grateful. Special thanks go to all of my postgraduate students, who have worked tirelessly with me. I wish you well in your future career endeavours. Every member of the Organic Research Group headed by Prof. Familoni is acknowledged for the role they played in my academic career and particularly, their assistance with the preparation of this inaugural lecture.

I am grateful to all my colleagues in Pharmaceutical Chemistry, CMUL where I obtained my Master's degree and Lagos State University where I started my career as a lecturer. Not forgetting wonderful colleagues at the Federal University of Agriculture, Abeokuta, where I did my Sabbatical leave last year. Thank you all for the great and memorable time spent with you .

My siblings, Otunba Olusegun & Mrs. Doja Ogunbanke; Mr Akintunde Sode; Retired Major Yomi & Mrs Olayemi Erinle; Mr Adedeji & Pastor Mrs Mosunmola Kehinde Adegboyega and Engr Bola & Mrs Abiodun Idowu Ogunnaike are acknowledged. I also remember the contributions of my late sister, Mrs. Tolulope Sode to my upbringing and Education. I say a big thank you to you all for your understanding, support and prayers over the years. I must also acknowledge the TunjiLaide Ogunbanke clan and the entire Asekun family, we have shared very good moments and have supported one another even during difficult times, thank you.

To all my friends, especially those present here today, I say thank you. Mrs Kemi Aina, Mrs Oyeyemi Ayoola, Mrs Wunmi Ajayi, Prof Oyedeji, Mrs Fabanwo, Mrs Ayeni and others, I treasure our friendship. I thank you for being true friends.

I am grateful to all my spiritual fathers, Pastor Bukola Akin-Aina, Pastor Akinbowale Alabi, Pastor Olatunde Oyegbami and Pastor Azuka Ogbolumani. Thank you for your spiritual guidance.

At this juncture , I would like to thank very sincerely my husband, Olalekan Asekun and our adorable children, Olabanji & Darasimi Asekun; Adebimpe Asekun; and Caleb and Ojuolape Oghenetega for all the care, support and understanding they have given to me. I thank my husband for allowing me fulfil my career dreams, he never at any point hindered my career. I thank you so much. My children, thank you for your love and understanding, especially while moving up and down without interference during my research trips.

Mr. Vice-Chancellor, Sir, lastly, I would like to thank everybody who has made this event possible, starting from the Inaugural lecture preparations, the setting of the hall, logistics, entertainment and all attendees, local, national and international. To all of you, I say thank you for being so gracious. For those who would be returning home either this evening, tomorrow or later, may God see you safely to your various destinations. God bless all of you.

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