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Determination of Aroma Components in *Vitex doniana* Fruit Syrup Following Hydrodistillation Extraction

Imoisi Chinyere and Iyasele Uche Julius

Department of Chemistry, University of Benin, Benin City, Nigeria. P.M.B. 1154, Benin City, Nigeria.
imoisi.chinyere@gmail.com

Abstract: The fresh fruits of black plum (*Vitex doniana*) were collected from several randomly selected trees in a farm site in Uromi metropolis, Esan North-East Local Government Area of Edo state and then processed into an extract in form of syrup. Hydrodistillation extraction (HDE) and GC-MS (HDE-GC-MS) were used to extract and analyse the volatile compounds, VOCs (aroma) respectively from black plum (*Vitex doniana*) fruit syrup and the percentage of each components were reported as raw area percentage based on the total ion current. 24 different volatile compounds (VOCs) were identified and were grouped into seven classes of organic compounds comprising of 8 terpenes, 5 carboxylic acids, 4 ketones, 2 lactones, 2 aldehydes, 2 ethers and 1 ester. The terpenes are alpha-thujene (0.22%), eucalyptol (34.86%), linalool (0.79%), Fenchol-exo (3.31%), terpinene-4-ol (8.01%), alpha terpineol acetate (4.29%), 3-butyl spathulenol (0.83%) and caryophyllene (0.52%). The carboxylic acids components are heptanoic acid (3.77%), n-octanoic acid (14.86%), 3-octenoic acid (0.61%), n-nonanoic acid (1.20%) and 3-Decenoic acid (16.91%). The ketones are acetylfuran (0.20%), lilac alcohol formate C (0.35%), P-hydroxylactophenone (0.76%), and cycloheptanone (2.24%). The aldehydes are benzaldehyde (1.79%) and lilac aldehyde B (0.79%). The Ethers are methyleugenol (0.67%) and caryophyllene oxide (1.04%). The lactones are 4-octanolide (0.91%) and Jasmine lactone (0.43%). Esters represent the least of the total volatile compounds identified, which is methyl cinnamate (0.47%). The aroma components are the characteristic odor active compounds in *Vitex doniana* fruit syrup. The aroma components could also contribute to the biomedical activities of the syrup, especially its antioxidant effect due to their natural radical scavenging potential. It is also suggested that further research should be carried out on its economic status and feasibility of the seed as feed supplement in animal feed. Proper exploitation of the fruit and utilization of the syrup can help conserve foreign exchange expended on the importation of syrup, and substitute for other syrups in industrial and food uses.

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1. Introduction

Black plum (*Vitex doniana*) is a plant widely used by several communities in Nigeria for many purposes, including production of wine and jam. Ripe mature black plum fruits for food use, usually are collected from the ground instead of plucked (Okigbo, 2001). With increasing emphasis on upgrading traditional plant food resources in Nigeria, there is the need for better understanding of available plants including the severally underutilized species. *Vitex doniana* represents one of our neglected underutilized forest resources. Although major research on the health benefits of plant-rich diets has lied emphasis on established vitamins, the current data are controversial and the drive towards identification of more constituents and plant food sources continues (Ochieng and Nandwa, 2010). In addition, the economic value of *Vitex doniana* has not been exploited to its maximum despite the documented uses. Black plum of the family verbanacae is a tree crop that grows in open woodland and savannah regions of tropical Africa; it is the commonest of Vitex species in West Africa. It produces fruits which are plum like, sweet and edible. The fruit is green when mature and changes to dark brown when fully ripe, with the pulp surrounding a hard stone containing 1 to 4 seeds. It is a savannah specie and therefore can be found in northern, western and eastern Nigeria.

Plants and other components of natural origin have being applied throughout the world for human and animal health care for age long time. This is especially in Africa where underdevelopment and poverty have made a large percentage of the people depend almost totally on traditional medical practices and folkloric application of plants (Ajoku et al., 2001; Enzo, 2006). The efficacy of some of these traditional herbal remedies has been shown by several researchers. One of such plant popular for it wide use in Africa native folklore is *V. Doniana* Sweet.

The plant is indigene to Nigeria, Botswana, Ethiopia, Kenya, Lesotho, Namibia, Niger, Senegal, Somalia, South Africa, Sudan, Tanzania, Uganda, Zambia. It is locally known as Vitex (English), dinya (Hausa), ucha koro (Igbo) and oori-nla (Yoruba) (Burkill, 2000; Glew et al., 1997). In folkloric medicine, various parts of the plant are used as remedy for infectious conditions such as infertility, anaemia, jaundice, leprosy, dysentery, colic, gonorrhea, backaches, headaches, febrifuge, conjunctivitis and other eye troubles, stiffness, measles, rash, fever, chickenpox, hemiplegia, as tonic galactagogue to aid milk production in lactating mothers, anodyne, ankylostomiasis (ancylostomiasis), rachitis, leprosy and liver disease, kidney troubles and dearth of vitamin A and B. the twigs are used as chewing sticks for cleaning the teeth. The blackish extract gotten by boiling the leaves, bark, root and/or fruits is applied as ink and dye for clothes (Burkill, 2000; Irvine, 1961). The generic name, 'Vitex', is an ancient Latin name for the genus. Apart from the commercial relevance of this plant in timber and wood production, not much research on its chemical and antimicrobial activity has been done. It is in the light of the above, that this work aim to link scientific findings with some of these folkloric uses with the intentions of attracting more research interest to plant in trending lead/hit prospects in drug discovery. Black plum are branded as juicy seed bearing structure of flowering plant that may be consumed as food (Hyson, 2002).

Fruits are not given the place they deserve in the diet of Nigerians due to lack awareness of their nutritive value, cost and challenges in storage and distribution (Sai, 1997). The diet of most rural and urban dwellers is deficient in protein resulting in increased incidence of malnutrition and rise in dietary diseases; a situation in which children and especially pregnant and lactating women are most susceptible (Black, 2003). In developing nations, various types of edible wild plants are exploited as sources of food to give supplementary nutrition to the inhabitants (Aberoumand and Deokule, 2009). Food and Agricultural Organization (FAO) reported that at least one billion people are assumed to use wild food in their food (Burhingame, 2000). In Ghana alone, the leaves of over 300 species of wild plants and fruits are eaten while about 150 wild plant species have been earmarked as sources of emergency food in India, Malaysia and Thailand (Umar et al., 2007). Also, in South Africa about 1400 edible plant species are consumed (Hassan and Umar, 2004). It is therefore paramount to note that the addition of edible wild and semi-cultivated plant resources could be valuable to nutritionally marginal populations, or to certain susceptible groups within the population, especially in developing countries where poverty and climatic changes are inflecting havoc to the rural dwellers (Aberoumand and Deokule, 2009).

The genus Vitex consists of over 270 species, mostly trees and shrubs, and is confined to tropical and sub-tropical regions, although some species are also present in the temperate zones (Padamalatha *et al*., 2009). Among them is *V. doniana* also called black plum. Information of its botany is reported by Agbede and Ibitoye (2007). Nnajiofor (2003) investigated the fermentation of *V. doniana* (black plum) juice for the preparation of wine, while Agbede and Ibitoye (2007) studied the sugar composition as well as the anti-nutritional components in its fruit. Egbekun et al. (1996) revealed that *V. doniana* fruit could serve as a vital source of nutritive sweetener while Ladeji et al. (2004) investigated the anti-diarrhoea potency of stem bark of *V. doniana*. Despite its application as food and medicine in this part of the world, there has been minimal or no report on its proximate, vitamin and mineral composition. There had been no worry about food security since 1930 in United States; the booming food export has even returned a beneficial effect on the economy. Many nations cannot lay claim to this because over 870 million people are malnourished or hungry according to the United Nations Food and Agriculture Organization (Woteki, 2013). There is a reason for other countries to resolve this fundamental issue of feeding their people in order to ensure food security. The dependence on some crop species (rice, maize, wheat and cassava) in the supply of calorie need demand of man and high cost of readily available fruits and vegetables are among the propelling forces behind micronutrients deficiency prevailing in Africa. While there had been many interventions through food bio-fortification, diet diversity is the most commendable approach. Strategies based on nutrient rich foods like vegetables are regarded essential to be a basic objective in the fight against malnutrition and under-nourishment. In Nigeria like most other African nations, rural dwellers depend on leaves collected from the wild as their major source of leafy vegetables. These vegetables include leaves of annuals and shrubs and also leaves of trees. Most often, the trees are considered as sources of fruits and seeds while their leaves are left to rot.

Aroma is the global integral perception of all the senses that are involved (smell, taste, sight, touch) in consuming food (Anzaldua, 1994). There are almost unlimited variations in the intensity and quality of odours that can be perceived by the specialised cells of the olfactory epithelium from the nasal cavity (Martín-Cuenca, 2006). The gustatory papillae situated on the (top of the) tongue and on the posterior part of the oral cavity facilitate the perception of sensations of sweetness, sharpness, saltiness and bitterness

(Sherwood, 2007; Nagodawithana, 1994). The detection of sensations of spiciness, coldness and umami (Grigorov, 2003) is realised by the cells from the trigeminus (Axel, 1995). The aromatic substances present a wide range of chemical structures that stem from the main constituents of food. They are characterised by the fact that they stimulate the receptors of smell and/or taste in order to produce an integrated psychological response.

2. Materials and Methods

The fresh fruits of black plum (*Vitex doniana*) were collected from several randomly selected trees in a farm site in Uromi metropolis, Esan-North East Local Government Area of Edo state. The plant was identified by the Ethnobotanist and registered with a voucher specimen number NIPRD/01/03/CCPF/384/3 and deposited at the herbarium of the National institute for pharmaceutical research and development (NIPRD), Idu Industrial area, Abuja.

Extraction was done using a modified method described by Abu (2002) and Aiwonegbe (2018). The fruits were kept under ambient temperature in the laboratory. The fruits were sorted to select the fresh ones and then cleansed to remove sand and other debris. Thereafter, washing with portable water and removal of the thin epicarp. The fruits were then milled through a 90 µm sieve to press out the succulent mesocarp and separate the stony seed from the pericarp. The pulp was blended in a waring blender for a few seconds and warm water at 30^{o}C was added to the mixture. The mixture was then stirred continuously for five minutes with a wooden paddle to obtain the syrup.

Hydrodistillation extraction (HDE) and GC-MS (HDE-GC-MS) were used to extract and analyse the volatile compounds (aroma) respectively from black plum (*Vitex doniana*) fruit syrup. According to the method described by Okhale et al. (2018). Volatile constituents of the sample were obtained by hydrodistillation and analysed by GC-MS using Shimadzu QP-2010 with QP-2010 Mass Selective Detector [MSD, operated in the EI mode (electron energy=70 eV) scan range of 45-700 amu, and scan rate of 3.99 scans/sec], and Shimadzu GC-MS solution data system. The Gas chromatography column was HP-5 MS fused silica capillary with 5% phenyl-methylpolysiloxane stationary phase, with length of 30 m, internal diameter of 0.25 mm and film thickness of 0.25 µm. The carrier gas was helium with flow rate of 1.61 mL/min. The program used for Gas chromatography oven temperature was 60-160 ^{0}C at a rate of 10 ^{0}C/min, then held at 160 ^{0}C for 2 min, followed by 160-280 ^{0}C at a rate of 15 ^{0}C/min, then again held at 280 ^{0}C for 4 min. The injection port temperature was 250 ^{0}C while ion source temperature was 200 ^{0}C; interface temperature was 250 ^{0}C. 1.0 µL of diluted sample (1% v/v in hexane) was injected using autosampler and in split mode with ratio of 20:80. Individual constituents were identified by comparing their mass spectra with known compounds and NIST Mass Special Library (NIST). The percentage of each component was reported as raw area percentage based on the total ion current.

3. Results

The results are shown in Figure and Table 1.

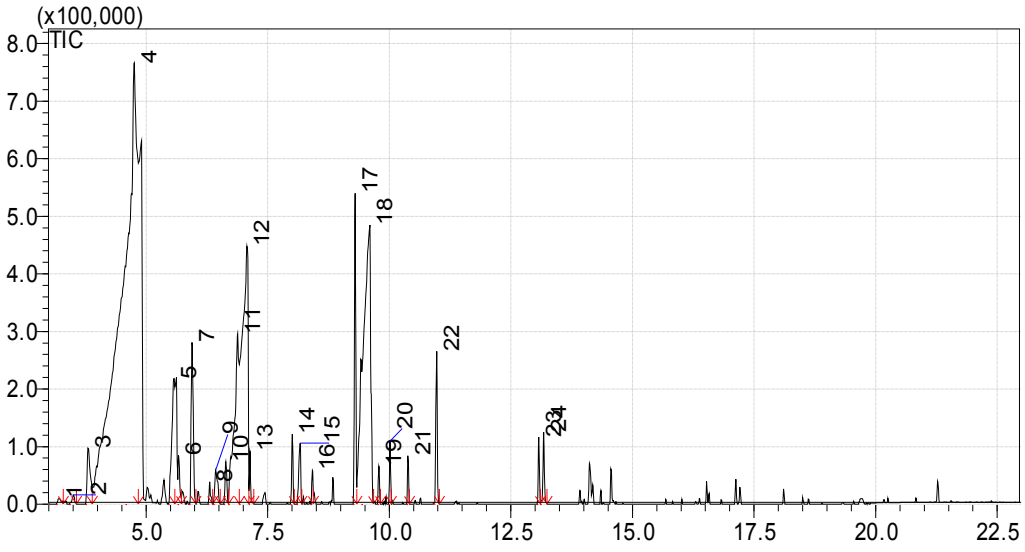

Figure 1: GC-MS Spectrum of the Aroma Components of *Vitex doniana* Fruit Syrup

Table 1: The Aroma Compounds Identified in *Vitex doniana* Fruit Syrup

Peak#	R.Time	I.Time	F.Time	Area	Area%	Height	Height%	A/H	Mark	Name
1	3.208	3.158	3.300	49985	0.20	9714	0.21	5.15		Acetylfuran
2	3.505	3.425	3.567	57036	0.22	16211	0.36	3.52		alpha.-Thujene
3	3.811	3.758	3.892	453424	1.79	97395	2.14	4.66		Benzaldehyde
4	4.755	4.583	4.842	8849198	34.86	766763	16.82	11.54	V	Eucalyptol
5	5.572	5.458	5.592	956952	3.77	218475	4.79	4.38		Heptanoic acid
6	5.669	5.650	5.725	201372	0.79	85019	1.86	2.37	V	Linalool
7	5.945	5.892	6.025	840574	3.31	281068	6.16	2.99		Fenchol, exo-
8	6.308	6.275	6.367	88737	0.35	38549	0.85	2.30		Lilac alcohol formate C
9	6.433	6.383	6.525	246579	0.97	59119	1.30	4.17		Lilac aldehyde B
10	6.639	6.600	6.692	191765	0.76	74108	1.63	2.59		p-Hydroxyacetophenone
11	6.881	6.692	6.917	2033091	8.01	295672	6.48	6.88	V	Terpinene-4-ol
12	7.075	6.917	7.117	3773673	14.86	448270	9.83	8.42	V	n-Octanoic acid
13	7.137	7.117	7.217	154047	0.61	92621	2.03	1.66	V	3-Octenoic acid
14	8.006	7.967	8.050	229973	0.91	121437	2.66	1.89		4-Octanolide
15	8.167	8.100	8.200	304582	1.20	106339	2.33	2.86		n-Nonanoic acid
16	8.420	8.392	8.442	108374	0.43	58919	1.29	1.84		Jasmine lactone
17	9.298	9.258	9.333	1090228	4.29	540188	11.85	2.02		alpha.-Terpineol acetate
18	9.597	9.433	9.675	4293362	16.91	485156	10.64	8.85	V	3-Decenoic acid,
19	9.787	9.758	9.817	118835	0.47	65850	1.44	1.80		Methyl cinnamate
20	10.016	9.983	10.042	169359	0.67	109387	2.40	1.55		Methyleugenol
21	10.385	10.358	10.417	133058	0.52	83965	1.84	1.58		Caryophyllene
22	10.974	10.925	11.033	568259	2.24	264640	5.80	2.15		Cycloheptanone, 3-butyl-
23	13.074	13.042	13.108	210918	0.83	116288	2.55	1.81		Spathulenol
24	13.174	13.108	13.242	264465	1.04	124756	2.74	2.12	V	Caryophyllene oxide
				25387846	100	4559909	100			

4. Discussion

Based on the percentage of each constituents and class of organic compounds contribution to the aroma profile as obtained from their raw area percentage based on the total ion current without standardization from table 1.

Like many stone fruits, plums (*Vitex doniana* fruit) are appreciated by consumer all over the world and, consequently, have gained great economic importance. The fruits are presently cultivated across tropical Africa and beyond. The crop is either marketed fresh or used as dried fruit and to produce juice. It is also used to make jams and other recipes or fermented to produce wine and brandy. Apart from colour, sweetness and texture, plums are especially popular for their characteristic aroma.

The produced syrup is comprised mainly of diverse classes of compounds, including terpenes, carboxylic acids, esters, ether, aldehyde, ketones and lactones. In all, 24 different volatile compounds were identified and were grouped into seven classes of organic compounds comprising of 8 terpenes, 5 carboxylic acid, 4 ketone, 2 lactones, 2 aldehydes 2 ethers and 1 ester.

Various types of fresh fruits were reported to produces distinct volatile profiles. Although an overwhelming number of chemical compounds have been identified as volatile compounds in fresh fruits, only a fraction of these compounds have been identified as impact compounds of fruit flavor based on their quantitative abundance and olfactory threshold.

An aroma compound, also known as an odorant, aroma, fragrance, or flavor, is a chemical compound that has a smell or odor. For a chemical compound to have a smell or odor it must be sufficiently volatile to be transported to the olfactory system in the upper part of the nose. Generally molecules meeting this specification have molecular weights of less than 300. Aroma compounds can be found in food, wine, spices, floral scent, perfumes, fragrance oils, and essential oils. For example, many form biochemically during the ripening of fruits and other crops. In wines, most form as by-products of fermentation. Also, many of the aroma compounds play a significant role in the production of flavorants, which are used in the food service industry to flavor, improve, and generally increase the appeal of their products.

Terpenes were found to be the most abundant volatile constituents as they accounted for the largest proportion of the total aroma (33.3%) and also had the highest impact of (52.83%) on the aroma note or

odour activity of the syrup. The terpenes are alpha-thujene: 0.22%, eucalyptol: 34.86%, linalool: 0.79%, Fenchol-exo: 3.31%, terpinene-4-ol: 8.01%, alpha-terpineol: 4.29%, 3-butyl spathulenol: 0.83% and caryophyllene: 0.52%. Terpene are a large and diverse class of organic compounds, produced by a variety of plants, particularly conifers, and by some insects (Davis and Croteau, 2000). They often have a strong odor and may protect the plants that produce them by deterring herbivores and by attracting predators and parasites of herbivores (Martin et al., 2003). Although sometimes used interchangeably with "terpenes", tepenoids (or isoprenoids) are modified terpenes as they contain additional functional groups, usually oxygen-containing (Martin et al., 2003). Terpenes are hydrocarbons. Terpenes are the major components of rosin and turpentine produced from resin. The name "terpene" is derived from the word "turpentine". Terpenes are also major biosynthetic building blocks. Steroids, for example, are derivatives of the triterpene squalene.

Terpenes and terpenoids are the primary constituents of the essential oils of many types of plants and flowers (Davis and Croteau, 2000). Essential oils are used widely as fragrances in perfumery and traditional medicine, such as aromatherapy. Synthetic variations and derivatives of natural terpenes and terpenoids also greatly expand the variety of aromas used in perfumery and flavors used in food additives.

Thujene which is commonly known as alpha thujene (3-thujene) and less commercially as 2-thujene, the IUPAC name 1-Isopropyl-4-methylbicyclo [3.1.0] hex-3-ene is a natural organic compound classified as a monoterpene. It is found in the essential oils of a variety of plants, and contributes pungency to the flavor of some herbs such as summer savory, *Vitex doniana* fruit.

Eucalyptol is a natural organic compound that is a colorless liquid. It is a cyclic ether and a monoterpenoid. Eucalyptol comprises up to 90% of the essential oil of some species of the generic product eucalyptus oil (Boland et al., 1991), hence the common name of the compound. It is also found in camphor laurel, bay leaves, tea tree, sweet basil, woomwood, rosemary, common sage, cannabis sativa and other aromatic plant foliage. Eucalyptol with a purity from 99.6 to 99.8% can be obtained in large quantities by fractional distillation of eucalyptol oil. Although it can be used internally as a flavoring and medicine ingredient at very low doses, typically of many essential oils (volatile oils), eucalyptol is toxic if ingested at higher than normal doses. Because of its pleasant, spicy aroma and taste, eucalyptol is used in flavorings, fragrances, and cosmetics. Eucalyptol has a fresh mint-like smell and a spicy, cooling taste.

Terpinen-4-ol is an isomer of terpineol with the chemical formula $C_{10}H_{18}O$. A primary constituent of tea tree oil, it is obtained as an extract from the leaves, branches, and bark of Melaleuca alternifolia Cheel (Hammer et al., 2012). It may be a factor in the contact dermatitis of tea tree oil when used topically (Hammer et al., 2012).

Linalool refers to two enantiomers of a naturally occurring terpene alcohol found in many flowers and spice plants. Found in many flowers and spice plants. These have multiple commercial applications, the majority of which are based on its pleasant scent (floral, with a touch of spiciness). It can be called linalyl alcohol.

Alpha Terpineol is a monoterpene alcohol that has been isolated from a variety of sources such as cajuput oil, pine oil, and petitgrain oil. There are four isomers, alpha-, beta-, gamma-terpineol, and terpinen-4-ol. Beta and gamma-terpineol differ only by the location of the double bond. It has a pleasant odor similar to lilac and is a common ingredient in perfumes, cosmetics, and flavors. It is one of the two most abundant aroma constituents of lapsang souchong tea. It originates in the pine smoke used to dry the tea (Yuasa, 2006).

3-butyl spathulenol is sesquiterpene alcohol first isolated from the essential oils of *Artemisia vulgaris* and *Artemisia dracunculus*. It has an earthy herbal fruity aroma, 3-butyl spathulenol also shows the capacity to inhibit proliferation in the lymphocytes, inducing apoptosis in these cells possibly through a caspase-3 independent pathway. Immunoinhibitory effect.

Caryophyllene, is a natural bicyclic sesquiterpene that is a constituent of many essential oils, especially clove oil, the oil from the stems and flowers of *Syzygium aromaticum* (cloves) (Ghelardini *et al*., 2001), the essential oil of cannabis sativa, rosemary, and hops (Ormeno *et al*., 2008). It is found as a mixture with isocaryophyllene (the *cis*-double bond isomer). Caryophyllene is notable for having a cyclobutane ring, as well as a trans-double bond in a 9-membered ring.

These compounds have already been identified in fresh plums (Crouzet, 1990; Williams and Ismail, 1981), and were reported as the major terpenoids in candied plum (Nunes et al., 2008). The monoterpenoids were reported as volatile constituents of fruits responsible for a wide spectrum of very pleasant aromas (Belitz, 2004). According to the studies of Williams and Ismail (1981) with *Prunus domestica*, linalool is very important in the aroma of European plums. Biochemical modifications such as oxidation or rearrangement of monoterpenes produce the related monoterpenoids (Stolle et al., 2009). Quite a few honey samples have been investigated and the

following monoterpenes and monoterpenoids were identified: linalool and its derivative, β-terpineol, dihydrocitronellol, β-citronellol, citronellal, geranyl acetone, limonene, β-pinene, tetrahydrogeraniol, cavacrol, p-cymene, 1, 8-cineol, camphor, isoborneol, p-cymenol *etc*. (Castro-Varquez et al., 2006; Pena et al., 2004). They are known to be active against a wide range of micro-organisms including Gram negative and positive bacteria, viruses as well as fungi (Inouye et al., 2001; Abd El-Moaty, 2010). Terpenes are a small and heterogeneous class of naturally occurring compounds that serve as important synthetic building blocks for the production of flavors, fragrance, pharmaceuticals and nutraceuticals. They are oligomers or polymers of isoprene and can be categorized depending on the number of isoprene units into monoterpenes, sesquiterpenes, diterpenes, triterpenes and tetraterpenes. With respect to occurrence in nature, the monoterpenes represent the most important and best investigated class of terpenic compounds. This class of compounds is also known for its biological activities in humans; limonene prevents mammary, liver, lung and other cancers acting in the promotion/progression stage (Tholl, 2006). Besides, their antimicrobial activity, these compounds possess antiseptic and disinfectant qualities and also very great stimulating therapeutic properties; however, they could cause side effects such as skin and mucous membrane irritation and toxicity.

The next most abundant compound, were carboxylic acid comprising (20.8%) of the total volatile components identified and had an impact of (37.35%) on the aroma note or odour activity of the syrup. Many carboxylic acids are colorless liquids with disagreeable odors. The carboxylic acids with 5 to 10 carbon atoms all have "goaty" odors (explaining the odor of Limburger cheese). Unlike esters which have sweet pleasant odors often associated with fruits, carboxylic acids are noted for their sour, disagreeable odors.

The carboxylic acids components are heptanoic acid: 3.77%, n-octanoic acid: 14.86%, 3-octenoic acid: 0.61%, n-nonanoic acid: 1.20% and 3-Decenoic acid: 16.91%. The molecular weight of organic acids varies widely from relatively small compounds (fatty acids) with higher numbers of carboxylic and phenolic functional groups. Monocarboxylic acids with 5-10 carbon with unpleasant smells. As the carbon chain length increases (greater than 10 carbon atoms) the acids are waxlike solids, and their smell diminishes with increasing molar mass and decreasing volatility.

The next most abundant components were ketones comprising (16.7%) of the total volatile components identified and had impact of (3.55%) on the aroma note or odour activity of the syrup. The ketones are acetylfuran: 0.20%, lilac alcohol formate C: 0.35%, P-hydroxylactophenone: 0.76%, and cycloheptanone: 2.24%. Ketones impart some very characteristics fragrance in compounds. For instance, ketones help in the formation of a compound "acetophenone" which is responsible for fragrances such as cherry, jasmine, honeysuckle, almond, strawberry, e.t.c.

Acetyfuran is a sweet balsam almond, nutty, brown and toasted with a milky, lactonic undernote. It is used in Chocolate, Coffee, Roast nut, Bread, Rum, Whiskey, Tamarind, Tea and Tobacco flavours, as a trace background note. 2-Acetylfuran is the most abundant flavor compound in tamarind, where its aroma, in conjunction with alpha-terpineol, citral and some trace pyrazines, contributes to the flavor.

Cyclohexanone is the organic compound with the formula $(CH_2)_5CO$. The molecule consists of a six-carbon cyclic molecule with a ketone functional group (Michael, 2005). This colorless oil has an odor reminiscent of that of acetone. Over time, samples of cycloheptanone assume a yellow color. Cyclohhexanone is slightly soluble in water and miscible with common organic solvents (Michael, 2005).

P-Hydroxyacetophenone or Piceol is a phenolic compound found in the needles and in mycorrhizal roots of Norway spruces (*Picea abies*) (Lokke, 1990). P-Hydroxyacetphenone monooxygenase is an enzyme that transforms piceol into 4-hydroxyphenylacetic acid. This enzyme is found in *Pseudomonas fluorescens* (Lokke, 1990).

The next most abundant compound, were aldehyde (benzaldehyde: 1.79% and lilac aldehyde B: 0.79%) comprised of (8.33%) and had impact of (2.76%) on the aroma note or odour activity of the syrup. Benzaldehyde is a characteristic constituent of skin waxes of plums having a fragrant, woody-like aroma (Ismail, 1980; Williams and Ismail, 1981). Benzaldehyde is an organic compound consisting of a benzene ring with a formyl substituent. It is the simplest aromatic aldehyde and one of the most industrially useful. It is a colorless liquid with a characteristic almond-like odor. The primary component of bitter almond oil, benzaldehyde can be extracted from a number of other natural sources (Scott and Scott, 1920). Synthetic benzaldehde is the flavoring agent in imitation almond extract, which is used to flavor cakes and other baked goods (Adams et al., 2005).

Aldehyde are well-known source of perfumes and fragrances in comparison to ketones. Aldehydes also play an important part in caramelization of sugars. During the process of caramelization, amino acids convert the aldehyde group present in sugar into unsaturated aldehyde thereby helping in the formation of caramel and the characteristic brown colour of

caramel. Aldehydes are also present in the herbs such as coriander and give it the characteristic smell of coriander.

Ethers (methyleugenol: 0.67% and caryophyllene oxide: 1.04%) comprising (8.33%) of total the volatile components identified and had impact of (1.71%) on the aroma note or odour activity of the syrup. Methyl eugenol is a natural chemical compound classified as a phenylpropene, a type of phenylpropanoid. It is the methyl ether of eugenol and its important behavior and pollination (Tan and Nishida, 2012). It is found in various essential oils. Methyl eugenol is found in a number of plants (over 450 species from 80 families including both angiosperm and gymnosperm families) and has a role in attracting pollinators. About 350 plant species have them as a component of floral fragrance. The compound (methyleugenol) can be evolved in response to pathogens, as it has some antifungal activity. It also repels many insects (Tan and Nishida, 2012). Caryophyllene oxide is the oxidized form of caryophyllene, one of the terpenes found in cannabis, as well as one of the major terpenes found in cloves, basil, hops, pepper, and rosemary.

The lactones (4-octanolide: 0.91% and Jasmine lactone: 0.43%) comprised of (8.33%) of the total volatile components identified and had impact of (1.34%) on the aroma note or odour activity of the syrup. Naturally occurring lactones are mainly saturated and unsaturated gamma and sigma-lactones. They are intramolecular esters of the corresponding hydroxyl fatty acids. They contribute to the aroma of fruits, butter, cheese, and other foods (Karl-Georg et al., 2007). Cyclopentadecanolide is responsible for the musklike odor of angelica root oil. Of the naturally occurring bicyclic lactones, phthalides are responsible for the odors of celery and lovage oils, and coumarin for woodruff (Karl-Georg et al., 2007). γ - octalactones, and γ-decalactones were also considered as important lactone contributors to the aroma of fresh plums (Williams and Ismail, 1981; Crouzet, 1990).

Jasmine lactone is a lactone and aroma compound with a powerful fatty-fruity peach and apricot flavor. Its chemical formula is $C_{10}H_{16}O_2$. It occurs naturally in jasmine oil, tuberose, gardenia, mimosa, honeysuckle, lily, tea, peach, and ginger. It is used as a food spice and is mainly used for the preparation of apricot, peach, diary products, and as a tropical fruit flavor.

4-Octanolide is commonly known as whisky lactone or quercus lactone is an important ingredient in the aromas of whiskey and other alcoholic beverages that have been aged in oak barrels. It is sometimes added to the liquor as a flavoring agents. It has a coconut, celery or fresh wood aroma that can be detected by humans at the concentration of 1 ug/L in air (Eric et al., 2000). A mixture of the *cis* and *trans*-isomers is repellent for mosquitos and flies (Yukio et al., 1992). The 3S, 4S isomer is extracted by the alcoholic beverage from some precursor substances in the oak wood. It can be synthesized from a cyclopentane derivative (Yukio et al., 1992).

These compounds are important compounds in terms of their contribution to the aroma and in general, present fruity odor descriptors. Utilizing crosses between *P. salicina* and *P. americanum*, Horvat *et al*. (1992) found that lactones were also a major class of volatile compounds in south eastern American plums. Previous studies reported γ-dodecalactone as the major lactone in Japanese plum (*P. salicina*) (Gomez, 1993) and candied plum (*P. domestica*) (Nunes, 2008).

Esters represent the least (4.2%) of the total volatile compounds identified which is methyl cinnamate: 0.47% and had the least impact of (0.47%) on the aroma note or odour activity of the syrup. Apart from methyl cinnamate, other esters are also well known in fruits for their sweet smelling fragrance, some of these esters are octyl ethanaote in orange, ethyl butanaote in cherry, butyl ethanaote in banana, ethyl methanaote in rum, linalyl butyrate in peach, linalyl acetate in lavender/sage, isobutyl acetate in strawberry, isoamyl formate in raspberry, methyl acetate in glue, methyl butyrate pineapple, methyl phenylacetate in honey, pentyl pentanoate in apple, propyl hexanoate in cheese, methyl pentanoate in flowery, methyl salicylate in wintergreen, ethyl acetate in butter, ethyl benzoate in sweet, methyl butanaote in apple, benzyl acetate in jasmine e.t.c. Esters formed from simple hydrocarbons groups are colorless, volatile liquids with pleasant aromas and create the fragrances and flavors of many flowers and fruits. They are also used as food flavorings. Larger esters, formed from long-chain carboxylic acids, commonly occur as animal and vegetable fats, oils, and waxes. Methyl cinnamate is the methyl ester of cinnamic acid and is a white or transparent solid with a strong, aromatic odor (Boland et al., 1991). It is found naturally in a variety of plants, including in fruits, like strawberry, and some culinary spices, such as Sichuan pepper and some varieties of basil (Vina et al., 2003). Eucalyptus olida has the highest known concentrations of methyl cinnamate (98%) with a 2-6% fresh weight yield in the leaf and twigs (Boland et al., 1991). But studies of the volatile compositions of plums found that the esters are qualitatively and quantitatively the most important class compounds (Crouzet, 1990). Also quantitatively, esters are the major components of the volatile composition of fresh plums (Crouzet, 1990). Studies on Japanese plum (*P. salicina*) indicated that esters were also the main volatile constituents from this fruit (Forrey and Flath, 1974; Gomez, 1993).

Conclusion

Aromas represent an extremely heterogenous group of molecules because of their botanical origin, their functional properties, and especially for the chemical structure and the reactivity they exhibit. They are present in some food products, as natural or added parts of a more complex formulation, aroma is responsible for the singular properties of many foods. Consequently, especially when having to design new food products, it is fundamental to take into account a detailed description of the structural characteristics of its aroma components. *Vitex doniana* fruit syrup has a unique flavor due to the presence of 24 aroma components.

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Corresponding Author:
Dr. Imoisi Chinyere
University of Benin (UNIBEN),
Benin City, Edo State, Nigeria.
Tel: +2347030746386
Email: imoisi.chinyere@gmail.com

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