Synthetic insecticides, phytochemicals and mosquito resistance

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ABSTRACT

Mosquitoes and other insects have continued to be nuisance to man. They have served as vectors of some of the world dreaded diseases plaguing the tropics. Malaria is said to be endemic in 117 countries with some 3.2 billion people living at risk all over the world and about 350 to 500 million clinical cases of malaria worldwide with over 1 million deaths annually. Other mosquito borne diseases of public health significance include yellow fever, dengue fever, chikungunya, filariasis and encephalitis all of which amounts to great economic loses. Programs aimed at the control of mosquitoes are reliant on the use of chemical based synthetic insecticides which have for years offered hope to man. However, with the recent spate of resistance to insecticides, man obviously needs to search for suitable alternatives which probably would replace current control measures and offer a lasting solution to the age long battle against insects. The use of phytochemicals as possible alternative to chemical insecticides might be one of such options which should be explored given their availability, potency and low cost effect. This review therefore takes a critical look at the subject of insecticide resistance, synthetic chemicals and mosquitoes.

Keywords: Insecticides, mosquitoes, resistance, phytochemicals.

INTRODUCTION

Current vector control strategies include chemical-based control measures, non-chemical-based control measures and biological control agents (Poopathi and Tyagi, 2006). Chemical-based control measures have dominated over other strategies over the years. Das et al. (2007) reported that repetitive use of man-made insecticides for mosquito control disrupts natural ecosystems and the biological control systems and has led to reemergence of and increase in mosquito populations. In their studies, (Zhang et al., 2011; Legner, 1995) it was also pointed out that the continuous use of chemical-based insecticides resulted in the development of resistance, detrimental effects on non-target organisms and human health problems. Consequently, they suggested the need for alternative control measures. This leaves biological control as a viable alternative. The use of biological control agents such as predatory fish (Becker and Ascher, 1998), bacteria (Chapman, 1974), protozoa (Murugesan et al., 2009), fungus (Kaya and Gaugler, 1993), nematodes (Mathur, 2003) and plant products (ICMR Bulletin, 2003) had shown promising results in the control of mosquito populations.

The emergence of insect vectors that are resistance to available insecticides coupled with the environmental and economic burden arising from continuous use of insecticides and the health problems caused by these vectors calls for urgent alternative control measures. In ancient times, herbal products were used as natural insecticides before the discovery of synthetic insecticides (Roark, 1947). Phyto-products, on account of their minimal hazardous effect on the environment and availability may serve as alternatives in the control of mosquitoes. Reports have shown that various phytochemicals are potent adulticidal and larvicidal agents (Sukumark et al., 1991; WHO, 2012). Sukumark et al. (1991) described approximately 1,200 plant species having potential insecticidal value, while WHO (2012) listed and discussed
344 plant species that only exhibited mosquitoicidal activity. In view of the discovery that plants from various families have shown some degree of activity against various developmental stages of insect vectors, there is a need to evaluate local Nigeria plants for their possible activity. It was therefore important to carry out this research.

**Synthetic insecticides**

Vector control is a central, critical component of all malaria control strategies (Etang et al., 2003). It relies primarily on two interventions: long-lasting insecticidal nets (LLINs) and indoor residual spraying (IRS). Use of both has increased significantly during the past 10 years as part of a drive towards universal coverage of all populations at risk, saving hundreds of thousands of lives (Etang et al., 2003). In sub-Saharan Africa, insecticide treated nets (ITNs) and indoor residual insecticide spraying (IRS) are the cornerstones of malaria vector control. The use of chemical insecticides still remains the predominant means of controlling insect vectors. However, the emergence of insect resistant species suggests an alternative replacement to these chemicals. Currently, pyrethroids are the only class of insecticides approved for treating bed nets or curtains because of their high effectiveness and strong excito repellent effect on mosquitoes, yet, low mammalian toxicity (Ranson et al., 2000). However, pyrethroid resistance in *An. gambiae s.s.* has been described in West, East and Central Africa (Etang et al., 2004; Ranson et al., 2000).

**Insecticide resistance**

Insecticide resistance is the term used to describe the situation in which the vectors are no longer killed by the standard dose of insecticide (they are no longer susceptible to the insecticide) or manage to avoid coming into contact with the insecticide. The emergence of insecticide resistance in a vector population is an evolutionary phenomenon (WHO, 2011a). Insecticide resistance is widespread; it is now reported in nearly two thirds of countries with ongoing malaria transmission (Etang et al., 2003). It affects all major vector species and all classes of insecticides (Etang et al., 2003). According to WHO (2011b), if nothing is done and insecticide resistance eventually leads to widespread failure of pyrethroids, the public health consequences would be devastating. Much of the progress achieved in reducing the burden of malaria would be lost. For example, current coverage with LLINs and IRS in the WHO African region is estimated to avert approximately 220,000 deaths among children under 5 years of age every year (WHO, 2011b). If pyrethroids were to lose most of their efficacy, more than 55% of the benefits of vector control would be lost, leading to approximately 120,000 deaths not averted (Etang et al., 2003).

**CLASSES OF INSECTICIDES**

**Pyrethroids**

Pyrethroids are synthetic chemicals whose structures mimic the natural insecticide pyrethrum. Pyrethrins are found in the flower heads of some plants belonging to the family *Asteraceae* (for example, *chrysanthemums*). These insecticides have the ability to knock down insects quickly. Pyrethrums can be degraded very easily by ultraviolet light which oxidizes the compounds. In general, this phenomenon leads to lower environmental risk.

Pyrethroids are used for both IRS and LLINs in the form of α-cypermethrin, bifenthrin, cyfluthrin, deltamethrin, permethrin, λ-cyhalothrin and etofenprox (WHO, 2006). These have been the chemicals of choice in public health for the past few decades due to their relatively low toxicity to humans, rapid knock-down effect, relative longevity (3 to 6 months when used for IRS) and low cost. They are the only insecticides used currently in WHO recommended LLINs (Brown, 2006).

Pyrethroids have many modes of action on the mosquito vector. They open sodium channels leading to continuous nerve excitation, paralysis and death of the vector (WHO, 2007). They also have an irritant effect, causing an excito-repellency response, resulting in hyperactivity, rapid knock-down, feeding inhibition, shorter landing times and undirected flight, all of which reduce the ability of vectors to bite (WHO, 2007).

**Organochlorines**

Organochlorines are used in IRS in the form of DDT, which was the insecticide used predominantly in the eradication campaigns of the 1950s (Etang et al., 2003). At the Stockholm Convention on Persistent Organic Pollutants in 2001, the use of DDT was banned for all applications except disease control due to its environmental effects when used in large volumes in agriculture. As the number of equally effective, efficient, alternative insecticides for public health is limited, continued use of DDT was permitted until “locally safe, effective and affordable alternatives are available for a sustainable transition from DDT”. A WHO position statement in 2006 (WHO, 2009) reasserted the public health value of DDT when used for IRS. Like pyrethroids, DDT has been popular because of its rapid knock-down effect, relative longevity (6 to 12 months when used for IRS) and low cost. Despite the chemical structural differences, DDT and pyrethroids have similar modes of action (WHO, 2007).

**Organophosphates**

Organophosphates comprise a vast range of chemicals, but
those recommended for use for IRS vector control are fenitrothion, malathion and pirimiphos-methyl (WHO, 1970). The insecticides in this class are highly effective but do not induce an excito-repellency response from the vector and in their current formulations have shorter residual activity (2 to 3 months when used for IRS) than pyrethroids and DDT (Insecticide Resistance Action Committee, 2011). In addition, the organophosphates currently used for malaria control are significantly more expensive than other insecticides. Organophosphates act on the mosquito vector by inhibiting cholinesterase, preventing breakdown of the neurotransmitter acetylcholine, resulting in neuromuscular overstimulation and death of the vector (WHO, 2007).

**Carbamates**

Carbamates are used for IRS vector control in the form of bendiocarb (WHO, 1970). Like organophosphates, this compound is highly effective and induces little or no excito-repellency response from the vector. It has short residual activity (2 to 6 months when used for IRS) and is more expensive than pyrethroids and DDT. The mode of action of carbamates is similar to that of organophosphates (WHO, 2007).

**MECHANISM OF RESISTANCE**

Insects acquire resistance to insecticides through various means. Resistant insects often exhibit more than one of these resistance mechanisms at the same time. Resistance mechanisms can be grouped into four categories (Etang et al., 2003).

**Target-site resistance**

This occurs when the site of action of an insecticide (typically within the nervous system) is modified in resistant strains such that the insecticide no longer binds effectively and the insect is therefore unaffected, or less affected by the insecticide. Resistance mutations, known as knock-down resistance (*kdr*) mutations can affect acetylcholinesterase, which is the molecular target of organophosphates and carbamates or voltage-gated sodium channels (for pyrethroids and DDT) (President’s Malaria Initiative, 2007; Sukhoruchenko and Dolzhenko, 2008). Similarly, cyclodiene (dieldrin) resistance is conferred by single nucleotide changes within the same codon of a gene for a γ-aminobutyric acid (GABA) receptor. At least five point mutations in the acetylcholinesterase insecticide-binding site were identified that singly or in concert causes varying degrees of reduced sensitivity to OPs and carbamate insecticides (Insecticide Resistance Action Committee, 2005).

**Metabolic resistance**

Metabolic resistance is related to the enzyme systems that all insects possess to detoxify foreign materials. It occurs when increased or modified activities of an enzyme system prevent the insecticide from reaching its intended site of action. The three main enzyme systems are: esterases, mono-oxygenases and glutathione S-transferases. While metabolic resistance is important for all four insecticide classes, different enzymes affect different classes (President’s Malaria Initiative, 2007; Sukhoruchenko and Dolzhenko, 2008). Metabolic resistance is the most common mechanism and often presents the greatest challenge. Insects use their internal enzyme systems to break down insecticides. Resistant strains may possess higher levels or more efficient forms of these enzymes. In addition to being more efficient, these enzyme systems also may have a broad spectrum of activity (that is, they can degrade many different insecticides) (Mouchet, 2008).

**Behavioural resistance**

This is any modification in insect behavior that helps it to avoid the lethal effects of insecticides. Several publications have suggested the existence of behavioural resistance and described changes in vectors’ feeding or resting behaviour to minimize contact with insecticides. Studies in New Guinea and the Solomon Islands showed that *Anopheles farauti* vectors stopped biting later in the night (23:00 to 03:00) after the introduction of indoor DDT spraying and instead bit only in the earlier part of the evening before humans were protected by sleeping in a sprayed room (Wood et al., 2010). In most cases, however, there are insufficient data to assess whether behavioural avoidance traits are genetic or adaptive; genetic traits could have major implications for the types of vector control interventions needed. All behavioural traits, however, may not be negative as they could lead mosquitoes to feed on non-human animals. It is also possible to initially mistake the decline of a vector species as behavioural resistance. This mechanism of resistance has been reported for several classes of insecticides including organochlorines, organophosphates, carbamates and pyrethroids (Mouchet, 2008).

**Cuticular/penetration resistance**

It is a reduced uptake of insecticide due to modifications in the insect cuticle that prevent or slows the absorption or penetration of insecticides. Examples of reduced penetration mechanisms are extremely limited and only
one study suggested correlation between cuticle thickness and pyrethroid resistance in An. Funestus (Sakine, 2012). Micro-array experiments identified two genes that encode cuticular proteins that are upregulated in pyrethroid-resistant strains of Anopheles mosquitoes. Experience with other insects suggests that if cuticular resistance emerges in mosquitoes it could have a significant impact when combined with other resistance mechanisms. Behavioural and cuticular resistance mechanisms are rarer than the other mechanisms and are perceived by most experts to be a lesser threat than chemical resistance.

**INSECTICIDE RESISTANCE DETECTION TECHNIQUES**

There are several phenogenetic methods available to diagnose resistance in populations of pest species which enable the assessment of how shifts in composition and structure of a population caused by pesticides may affect its development geographically and over time. Among these, easy-to-use toxicological methods have gained the most recognition worldwide. They enable the determination of levels of population susceptibility to pesticides used in relation to the relative ratio of resistant and susceptible genotypes (Devonshire et al., 1996). Resistance can be determined by using conventional standard bioassay methods published by International Resistance Action Committee (IRAC) and biochemical, immunological and molecular methods.

**Conventional detection methods**

The standard method of detection is to take sample of insects from the field and rear them through to the next generations. Larvae or adults are tested for resistance by assessing their mortality after exposure to a range of doses of an insecticide. For susceptible and field populations, LD$_{50}$ or LC$_{50}$ values were calculated by using probit analysis.

The results are compared with those from standard susceptible populations. These methods include some differences for the different pest species. These methods are published by Insecticide Resistance Action Committee (Redwane et al., 2002). The other traditional method of detecting insecticide resistance is to expose individual insects to a diagnostic single dose for a set time period in a chamber impregnated with the insecticide or on a filter paper impregnated with the insecticide. These tests only give an indication of the presence and frequency of resistance and limited information can be gained as to the resistance mechanism (Devonshire et al., 1996).

Evolution of resistance is most often based on one or a few genes with major effect. Before a susceptible population is exposed to an insecticide, resistance genes are usually rare because they typically reduce fitness in the absence of the insecticide. When an insecticide is used repeatedly, strong selection for resistance overcomes the normally relatively minor fitness costs associated with resistance when the population is not exposed to insecticide (Devonshire et al., 1996).

**Immunological detection methods**

This method is available only for specific elevated esterases in collaboration with laboratories that have access to the antiserum. There are no monoclonal antibodies, as yet, available for this purpose. An antiserum was prepared against E4 carboxylesterase in the aphid Myzus persicae. An affinity purified IgG fraction from this antiserum was used in a simple immunoassay to discriminate between the three common resistant variants of M. persicae found in the UK field populations (Ansari et al., 2000).

**Biochemical detection of insecticide resistance**

Biochemical assays/techniques may be used to establish the mechanism involved in resistance. When a population is well characterized some of the biochemical assays can be used to measure changes in resistance gene frequencies in field populations under different selection pressure (Devonshire et al., 1996).

**Detection of monooxygenase (cytocrome P450) based insecticide resistance**

The levels of oxidase activity in individual pests are relatively low and no reliable microtitre plate or dot-blot assay has been developed to measure p450 activity in single insects. The p450s are also a complex family of enzymes and it appears that different cytochromes p450s produce resistance to different insecticides (Devonshire et al., 1996).

**PHYTOCHEMICALS AS LARVICIDAL AGENTS**

The use of plant products is an evolving alternative for mosquito control. The search for herbal preparations that do not produce any adverse effects in the non-target organisms and are easily biodegradable remains a top research issue for scientists associated with alternative vector control (Kamaraj et al., 2011). The plant kingdom has shown to be a reservoir of various chemicals used for various beneficial purposes by man. From the time of creation, it was recorded that trees were to be used as source of medicine. Today, with the advent of biotechnology and the discovery of certain potent phyto-components, the scope of usage of plant was extended. The phytochemical compounds obtained from the huge diversity of plant species from the tropical forest are
important sources of safe and biodegradable chemicals which can be screened for lavi
cidal activities (Okigbo et al., 2010). Many plants from varying families have proved to be
potent against the larva stage of mosquitoes. Arivoli et al. (2012) reported moderate larv
cidal effect of Annona squamosa, Chrysanthemum indicum, Tridax procumbens
against Anopheles subpictus and Culex spp. Kumar et al. (2007) also reported the larv
cidal effect of Azadirachta indica (neem tree), Ocimum gratissimum (scent leaf) and
Hyptis suaveolens (pignut weed) against mosquito larvae. Bishnu and Zeev (2005) reported
the larvicidal efficacy of plant extracts against the malaria vector Anopheles
stephensi. The larvical effect of Lantana Camara Linn against Aedes aegypti and Culex
quinquefasciatus was also evaluated by Abdullahi et al. (2011). Ademola and Ellof
(2011) reported that extracts of Balanites aegyptiaca (desert date) showed larvical effect on
C. pipiens. Studies on the larvical efficacy of aqueous extracts of Striga
hermonthica (Delile) Benth and Mitracar pusscaber (Zucc) on C. quinquefasciatus (culicidae) mosquito larvae was
conducted by Obomanu et al. (2006). Mgbemena (2010) studied the Anthelmintic efficacy of cashew
(Anacardium occidentale L) on in vitro susceptibility of the ova and
larvae of Haemonchus contortus. Kalu et al. (2010), studied the Larvicidal properties of Lepidagathis alope curoids and
A. indica on Anopheles gambiae and C. quinquefasciatus. Dibua et al. (2013), studied the comparative evaluation of
Larvicidal potentials of ethanol extracts of A. indica, O. gratissimum and C. citratus on Ae. aegypti larvae. The larvical activities of ethanol extract of Allium sativum
(garlic bulb) against the filarial vector, C. quinquefasciatus was reported by Nwabor et al. (2011). Osayemwenre et al.
(2014), Bickii et al. (2006) and Hostettmann and Marston (1995) reported the larvicidal effect of Picrali manitida
against A. gambiae.

**MAJOR PHYTOCHEMICALS FROM PLANT**

Phytochemicals are naturally occurring, biologically active
chemical compounds in plants. The prefix “Phyto” is from a
Greek word meaning plant. In plants, phytochemicals act as
a natural defense system for host plants and provide colour,
aroma and flavour. More than 4000 of these compounds
have been discovered to date and it is expected that
scientists will discover many more. Any one serving of
vegetables could provide as many as 100 different phytochemicals. Phytochemicals are protective and
disease-preventing. These natural chemicals have been
found useful to man in various ways. Phytochemicals have
been used both as food and medicine. Their activity against
micro-organisms prompts their use as anti-bacteria, anti-
fungal and anti-nematode agents. For instance, Harborne,
(1993) used an in vitro test for fifteen crude extracts from
the stem bark and seeds of four medicinal plants
(Entandrophragma angolense, Picralima nitida,
Schumanniophyton magnificum and Thomandersia hensii) to
check their anti-malarial activity against the chloroquine-
resistant Plasmodium falciparum W2 strain. The results
showed that the extracts of these plants possessed some
anti-malarial activity; he however reported that the
methanol extract of P. nitida demonstrated the highest
activity in vitro. Further isolation and identification of some
active compounds from these plants could justify their
common use in traditional medicine for the treatment of
malaria or fever in Cameroon. Besides the use of plants for
treatment of ailments, plants and their phytochemicals
have long been used from ancient times as a source of
insect repellant or insecticidal agents. Some of the
chemicals found in plants include:

**Saponin**

Saponins are glycosides with distinctive foaming
characteristics. They are natural detergents found in
certain plants. They are found in many plants especially
certain desert plants. Saponins are freely soluble in both
organic solvents and water (Pierpoint, 2000). Saponins
have detergent or surfactant properties because they
contain both water soluble and fat soluble components.
They are amphipathic compounds, possessing both
hydrophilic and lipophilic portions. They are therefore
surface active agents and can be used as emulsifiers. At
concentrations between 200 to 500 ppm, saponins exits as
monomers, above 500 ppm they aggregate as micelles with
a molecular weight of approximately 100,000 Da.

**Flavonoid**

Flavonoids are polyphenolic compounds comprising fifteen
carbons, with two aromatic rings connected by a three-
carbon bridge. They are the most numerous of the
phenolics and are found throughout the plant kingdom
(Crozier et al., 2006). They are present in high
concentrations in the epidermis of leaves and the skin of
fruits and have important and varied roles as secondary
metabolites. In plants, flavonoids are involved in such
diverse processes as UV protection, pigmentation,
stimulation of nitrogen-fixing nodules and disease
resistance (Katie et al., 2006).

The main subclasses of flavonoids are the flavones,
flavonols, flavan-3-ols, isoflavones, flavanones and
anthocyanidins. Other flavonoid groups, which
quantitatively are in comparison with minor components of
the diet are dihydroflavonols, flavan-3,4-diols, coumarins,
chalcones, dihydrochalcones and aurones. The basic
flavonoid skeleton can have numerous substituents. Hydroxyl
groups are usually present at the 4’, 5 and 7
positions.

Sugars are very common with the majority of flavonoids
existing naturally as glycosides. Whereas both sugars and hydroxyl groups increase the water solubility of flavonoids and other substituents such as methyl groups and isopentyl units, make flavonoids lipophilic (McGee, 2004).

**Tannin**

They are general descriptive names for a group of polymeric phenolic substances capable of tanning leather or precipitating gelatin from solution, a property known as astrinency. Their molecular weight ranges from 500 to 3000 kDa. The tannin compounds are widely distributed in many species of plants, where they play a role in protection from predation and perhaps also as pesticides and in plant growth regulation (Meyer et al., 2006). The astrinency from the tannins is what causes the dry and puckery feeling in the mouth following the consumption of unripened fruit or red wine (Sarker and Nahar, 2007). Likewise, the destruction or modification of tannins with time plays an important role in the ripening of fruit and the aging of wine. Tannins are divided into two groups, hydrolysable and condensed tannins.

Hydrolysable tannins are based on gallic acid, usually as multiple esters with D-glucose, while the more numerous condensed tannins (often called proanthocyanidins) are derived from flavonoid monomers. Tannins may be formed by condensation of flavon derivatives transported to woody tissues of plants. Alternatively, tannins may be formed by polymerization of quinine units.

**Alkaloids**

They are natural plant compounds with a basic character and usually contain one or more nitrogen atom in a heterocyclic ring. They are usually colourless, crystalline, non-volatile solids which are insoluble in water but soluble in ethanol, ether, chloroform and other organic solvents. Only very few are liquids which are soluble in water. Most alkaloids have a bitter taste and are optically active. Most alkaloids are physiologically active while some are extremely poisonous. The first medically useful example of an alkaloid was morphine isolated in 1805 from *Papaver somniferum* (Pium). Alkaloid constitutes the major phytochemical of *P. nitida* (Meyer et al., 2006). Many of its alkaloids are akuammine derivatives, this probably may be the origin of the name “akuamma plant”.

**Glycoside**

These are compounds that yield one or more sugars upon hydrolysis. A glycoside is composed of two moieties: sugar portion (glycone) and non-sugar portion (aglycone or genin). Glycosides of many different aglycones are extensively found in the plant kingdom (Sarker and Nahar, 2007). Many of these glycosides are formed from phenols, polyphenols, steroidal and terpenoidal alcohols through glycosidic attachment to sugars. Among the sugars found in natural glycosides, D-glucose is the most prevalent one, but L-rhamnose, D- and L-fructose and L-arabinose also occur quite frequently. Of the pentoses, L-arabinose is more common than D-xylene and the sugars often occur as oligosaccharides. The sugar moiety of a glycoside can be joined to the aglycone in various ways, the most common being through an oxygen atom (O-glycoside). However, this bridging atom can also be a carbon (C-glycoside), nitrogen (N-glycoside) or a sulphur atom (S-glycoside). By virtue of the aglycone and/or sugar, glycosides are extremely important pharmaceutically and medicinally. For example, digitoxin is a cardiac glycoside found in the foxglove plant (*Digitalis purpurea*).

Glycosides that exert a prominent effect on heart muscle are called cardiac glycosides, for example, digitoxin from *D. purpurea*. Their effect is specifically on myocardial contraction and atrioventricular conduction (Sarker and Nahar, 2007). Cardiac glycosides are found only in a few plant families, for example, *Liliaceae, Ranunculaceae, Apocynaceae and Scrophulariaceae* are the major sources of these glycosides. Among the cardiac glycosides isolated to date, digitoxin and digoxin, isolated from *D. purpurea* and *Digitalis lanata*, respectively, are the two most important cardiotonics. Digitoxin and digoxin are also found in in *Strophanthus* seeds and squill (Sarker and Nahar, 2007).

**Steroids**

Steroids are chemical messengers, also known as hormones. They are synthesized in glands and delivered by the bloodstream to target tissues to stimulate or inhibit some process. Steroids are nonpolar and therefore lipids. Their non-polar character allows them to cross cell membranes, so they can leave the cells in which they are synthesized and enter their target cells (Sarker and Nahar, 2007).

Structurally, a steroid is a lipid characterized by a carbon skeleton with four fused rings. All steroids are derived from the acetyl CoA biosynthetic pathway. Hundreds of distinct steroids were identified in plants, animals and fungi and most of them have interesting biological activity (Sarker and Nahar, 2007). They have a common basic ring structures, three-fused cyclohexane rings, together the phenanthrene part, fused to a cyclopentane ring system, known as cyclopentaphenanthrene.

The main feature of steroid, as in all lipids, is the presence of a large number of carbon-hydrogens that makes steroids non-polar. The solubility of steroids in non-polar organic solvents, for example, ether, chloroform, acetone and benzene and general insolubility in water results from their significant hydrocarbon components. However, with the
increase in number of hydroxyl or other polar functional groups on the steroid skeleton, the solubility in polar solvents increases.

Terpenoid

Terpenoids are compounds derived from a combination of two or more isoprene units. Isoprene is a five carbon unit, chemically known as 2-methyl-1,3-butadiene. According to the isoprene rule proposed by Leopold Ruzicka, terpenoids arise from head-to-tail joining of isoprene units. Carbon 1 is called the ‘head’ and carbon 4 is the ‘tail’ (Sarker and Nahar, 2007). Terpenoids are found in all parts of higher plants and occur in mosses, liverworts, algae and lichens. Terpenoids of insect and microbial origins have also been found. Terpenoids are classified according to the number of isoprene units involved in the formation of these compounds (Sarker and Nahar, 2007).

CONCLUSION

Chemical based insecticides are undoubtedly potent in their role as the choice option in the control and prevention of insect related illnesses. They have for ages been used in various strata as the only reliable alternative in the fight against insect vectors. Their role also in agriculture as the pesticides of choice in the control of pest which were major source of economic loss on farmers cannot be over emphasized nor can it be overlooked. However, irrespective of these roles, their detrimental effect on the environment and the eco-system as a whole calls for a review of their use. Chemical based insecticides have been shown to exhibit some levels of toxicity on humans and other non-target organisms. In view of these, various regulations has been enacted concerning their use while the use of few were total bond. Again, with their prolonged use, various insects have developed various means of cushioning their effect, hence, the occurrence of insecticide resistance. This therefore calls for a change of strategy in the fight against insect vectors.

Phytochemicals given their activity eco-friendliness and non-toxic effect on non target organisms might offer some hope in this fight, however, there is need to develop for extensive research on the activity of these phytochemicals. The active ingredient in these plants should be identified, extracted and possibly compounded for easy usage. The application of column and thin layer chromatography (TLC) to purify and isolate specific toxic phytochemical with bioactive potentials requires urgent attention. Determination of the structure of active ingredients by Infra Red (IR) Spectroscopy, Nuclear Magnetic Resonance (NMR), Gas Chromatography and Mass Spectroscopy (GCMS) analysis and studies on the effects of active ingredient on non target organisms should be further studied.

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