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Review
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Review

The role of spices in nutrition and health: a review of three popular spices used in Southern Nigeria

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Abstract

OBJECTIVES: Spices are increasingly finding other useful roles in healthcare aside their primary use as organoleptic enhancers in culinary. Several herbs and spices are currently being investigated for their potential health benefits, hence the explosion in scientific literature in the fields of nutraceuticals and functional foods. The rise in interest on medicinal properties of herbs and spices is consequent on the failing efficacy and toxicity associated with conventional drugs and their inaccessibility to poor rural dwellers. This work reviews three piquant spices; *Piper guineense*, *Afromomum melegueta*, and *Tetrapleura tetrapetra* common in the culinary of the Southern part of Nigeria, and it aims at concisely highlighting the researches that have been done on the nutritional quality, phytochemistry, and medicinal properties of these spices.
MATERIALS AND METHOD: A large body of peer-reviewed articles, most of them indexed in PubMed, were consulted for the purpose of the present review.
CONCLUSION: The overarching conclusion from the reviewed publications is the validation of most of the ethnomedical uses of these spices. The authors hope that this concise presentation on these spices will guide subsequent research in this field.

Key words: *Piper guineense*; *Aframomum melegueta*; *Tetrapleura tetraptera*; spices; nutraceuticals.

Introduction

Herbs and spices are plant-derived seasonings used for culinary purposes. The terms 'herbs' and 'spices' are often used interchangeably, but they have specific definitions in botany. Herbs store flavor component in their leaves, whereas spices store theirs in seeds, bark, and root. A spice may be the bud (clove), bark (cinnamon), root (ginger), aromatic seed (cumin), and flower stigma (saffron) of a plant. In addition to making food taste good, culinary spices have been used as food preservatives and for their health-enhancing properties for centuries (Kaefer and Milner, 2011). Moreover, for people of the world, spices stimulate appetite and create visual appeals to food (Opara and Chohan, 2014).

The use of spices in culinary predates recorded history and is said to have been an integral part of local dishes in South Asia and the Middle East as far back as 2000 BCE (Tapsell *et al*., 2006). The legendary Christopher Columbus' explorations in 1492 were in search of herbs and spices (Kaefer and Milner, 2011). In Mesopotamia, the cradle of civilization where agriculture began, there is evidence that humans were using thyme for their health properties as early as 5000 BC and were growing garlic as early as 3000 BC (Singletary, 2016). Spices are often gathered from plants when they have stopped flowering.

Spices are functional foods, these are foods that can be demonstrated to have a beneficial effect on certain target functions in the body beyond basic nutritional requirements (Lobo *et al*., 2010).

Spices occur in a variety of flavor, color, and aroma contributing a wide range of nutrients to foods (Mann, 2011). They enhance and complement flavor in foods with no detrimental effect on the organoleptic quality of the food (Kaefer and Milner, 2011).

Herbs and spices elaborate secondary metabolites that form part of the plants' chemical defense. They make food taste good but may not be delicious themselves, and many of them possess marked pharmacological and medicinal properties (Newman and Cragg, 2012). Their constituents function as defense chemicals to repel insects, snails, and other animals, and to kill microbes especially parasitic fungi (Adeyemi, 2011). They sometimes contain allelochemicals, used by certain plants (such as *Thymus vulgaris*) to inhibit the growth of other plant species around them (Linhart *et al.*, 2015). The importance of spices is underscored by the fact that they are still found in 40% of drugs prescribed till date (Mann, 2011).

Spices and herbs are revered for their potential health attributes. They are reported to have positive effects in the treatment of numerous diseases, especially chronic ones such as cancer, diabetes, and cardiovascular diseases (Kaefer and Milner, 2011). That nutrition and health are intricately linked is a well-established fact, and the ability of nutrition (in this case, nutrients from spices) to reduce the risk of diseases has engaged the attention of researchers and nutritionist alike in recent decades. Numerous epidemiological, preclinical, and clinical studies providing insights into the mode of action of this relationship has been carried out (Kochhar, 2008; Krishnaswamy, 2008; Iyer *et al.*, 2009).

The rise in demand for cheaper and safer therapeutics due to high cost and apprehension around the side effects of conventional drugs is stimulating interest in the use of phytomedicine for treatment, and management of diseases (Sigh, 2007; Dolui and Segupta, 2012).

The Nigerian culinary holds a wide and colorful array of spices which makes the country an important center for spices and herbs. In Nigeria, spices are not only used in culinary but also as galenicals in folk medicine for their putative health benefits. In times past, spices were used primarily for their organoleptic and preservative properties; however, recent studies on their medicinal and nutritional properties have opened new vistas in the fields of nutraceuticals and functional foods. A number of these studies have come up with exciting results; for example, antioxidants from spices, such as curcumin (turmeric), eugenol (clove), and capsaicin (red pepper), were experimentally shown to control oxidative stress in cells due to their antioxidant properties and their capacity to block the production of oxygen radicals in aerobic metabolism and interfering with signal transduction pathways (Rubió *et al.*, 2013; Srinivasan, 2014). Polyphenols from ginger (*Zingiber officinale*) and turmeric (*Curcuma longa* L.) have also been shown to display radical scavenging properties (Scalbert and Williamson, 2000).

This work aims to review previous works done on the nutritional and health benefits of three selected spices—*Piper guineense*, *Afromomum melegueta*, *Tetrapleura tetrapetra*—commonly used in Southern Nigerian culinary with the view to give a summary of what the prospects are for these spices, especially as regards their potential in formulating nutraceuticals used in chronic disease intervention.

Piper guineense Schum and Thonn (Piperaceae)

Description

Piper guineense Schum and Thonn (Piperaceae) is commonly known as African black pepper, 'uziza' in Igbo South East, and 'iyeree' in Yoruba south Western Nigeria. The plant is also known as Ashanti pepper, Benin pepper, Guinea pepper, and false cubeb in other parts of Africa. There are over 700 species of this plant which grows in tropical and sub-tropical Africa (Besong *et al.*, 2016). They have prolate spheroid seeds, native to Central and Western Africa, are semi-cultivated in Nigeria (Klin-Kabari, 2011). The plant is used for culinary, medicinal, cosmetics, and insecticidal purposes (Martins, 2013; Anyawu and Nwosu, 2014).

Folkloric and ethnomedical uses

P. guineense parts are widely used in South East Nigeria for its nutritional and medicinal properties (Ekanem *et al.*, 2010). The plant is used as a spice for its pungent and flavorful characteristic for soup preparation for post-parturient women (Chiwendu *et al.*, 2016). In the South Eastern parts of Nigeria, the seeds are prescribed for women after childbirth to enhance uterine contraction enabling expulsion of the placenta and other remains from the womb (Ekanem *et al.*, 2010). It is also used locally in treating rheumatic pains, as an anti-asthmatic agent (Sofowora, 1982) and also in weight control (Mba, 1994). The oil distillate from the seeds is used in perfumery and for making soap. The leaves are used to regulate menstrual cycle and as an ingredient in remedies for female infertility (Iwu, 2014). The root and fruits are incorporated in remedy for sexually transmitted diseases, especially gonorrhea and syphilis (Iwu, 2014).

Phytochemistry

The different parts of the plant have been characterized and its constituents determined. Phytochemicals are bioactive compounds found in plants. They are not vitamins or minerals but are constituents in the plant that work with other nutrients and dietary fibers to prevent and protect against diseases (Okoye and Ebeledike, 2013). Chiwendu *et al.*, (2016) in their quantitative analysis indicated (%) that seeds of *P. guineense* had alkaloids—0.86, saponins—1.87, tannins—1.19, flavonoids—0.72, and polyphenols—0.66. They reported a substantial amount of HCN (an anti-nutrient) 8.87%. Its essential oil had 10% myristicin, elemecin, safrols, and dilapoil. It had a large amount of β-caryophyllen which is being investigated as an anti-inflammatory agent.

They also screened the leaf extract and detected the presence of alkaloids, flavonoids, tannins, saponins, terpenes, resins, and phenols. The presence of alkaloids in both the leaves and seed extracts show that the plant possesses medicinal properties. Alkaloids are made up of heterocyclic nitrogen that has been shown to exhibit antimalarial, antihypertensive, antiarrhythmic, and anticancer properties (Heikens *et al.*, 1995). Alkaloids have also been reported to act as CNS stimulant and powerful analgesics (Ashok and Upadhyaya, 2012).

Saponins have been reported to have antimalarial effect (Besong *et al.*, 2016). The quantity of saponins (1.88%) detected in the leaves of this plant supports its antimalarial activity.

Other chemicals found in *P. guineense* are cardiac glycosides which are known to be important in the management of cardiovascular diseases. Flavonoids have been reported to possess antioxidant, anti-inflammatory, antitumor, antiallergic, and antiplatelet activity (Pal and Verma, 2013). The essential oils—dillapiol, piperine (5%–8%), elemicine, myristicine (10%), and safrole—show bactericidal and antimicrobial activity on some microorganisms (Klin-Kabari *et al.*, 2011). The chemical—piperine—which gives *Piper* plant family their 'heat' is about 5% to 10% of the content. The plant has an appreciable amount of β-caryophyllene which is undergoing investigation as an anti-inflammatory candidate (Issac, 2012).

Nutritional profile

The nutritional evaluation of *P. guineense* has been carried out in many studies (Udusoro and Ekanem, 2013; Nwakwo *et al.*, 2014;

Okonkwo and Ogu, 2014; Besong *et al.*, 2016). The proximate analysis indicates that the plant has crude protein, carbohydrates, fat, vitamins, and minerals (Nwakwo *et al.*, 2014). The essential oil content of the plant is appreciable, and is between 0.1% and 5%, which is significantly lower than the oil from another spice *Xylopia aethiopica*—16.30% (Ezekwesili *et al.*, 2010). The low peroxide, acid value, and free fatty acid content of this plant oil point to lower susceptibility to rancidity (Ogbunugafor *et al.*, 2011). The macromineral mineral content of spices is generally low (Omotayo *et al.*, 2013). However, the calcium content of *P. guineense* is high, quite comparable to the herb *O. basilium* which indicates that the plant when consumed could support the building of bones and teeth (Omotayo *et al.*, 2013). *P. guineense* contains vitamin A, C, and E and traces of vitamin B_1, B_2, and B_3. The presence of vitamin E points to the antioxidant capacity of the plant (Ogbunugafor *et al.*, 2011). The appreciable amount of vitamin C indicates that it supports the formation of healthy gum, teeth, and for the healing process.

Figure 1. Dry seeds of *P. guineense*.

Biological Activities

Effect on reproductive system

The effect on uterine physiology

The effect of *P. guineense* leaf extract on uterine contraction, similar to estrogen, *in vivo* has been reported by Udoh *et al.* (1999). Its traditional use after childbirth in soup preparation to enhance uterine expulsion of placenta and other remains from the womb was corroborated by this study. Udoh *et al.* (2012) also reported the cholinergic activity of the leaf extract on uterine muscle. They also submitted that its uterotonic action could be attributed to the alkaloid content. Their result also showed that the leaf extract induced uterine weight increase in immature female rats (Udoh *et al.*, 1999).

The effect on reproductive functions in rats

Mbongue *et al.* (2005) investigated the effect of dry fruits of *P. guineense* on the reproductive functions of adult male rats. In their study, the administration of the aqueous extract of fruits of the plant at two doses (122.5 and 245 mg kg^{-1}) for a duration of 8 and 55 days had a positive impact on the male reproductive functions by stimulating the secretions of the testes, epididymis, and seminal vesicles. However, there was a significant decrease in α-glucosidase and fructose levels both of which play important

Figure 2. Top panel (L-R): dry fruit and seeds of *A. melegueta*; bottom panel: Dehusked fruit of *A. melegueta*.

Figure 3. Top panel: dry fruits of *T. tetraptera*; bottom panel: dry seeds of the plant.

role in the motility of spermatozoa; and thus, the reduction (20%) in fecundity observed. The effect of water and ethanol extracts of dried fruits of a close relative *Piper nigrum* on the fertility potential in male albino rats had a positive impact on androgenic hormone level and fertility potential in animals (Sutyarso and Kanedi, 2016)

Effect on conception in mice

The effect of the ethanol seed extract on conception in mice as reported by Ekanem *et al.*, (2010) indicated that there was no occurrence of conception in the female mice after a 21-day administration (at various concentrations 10, 20, 30, and 40 mg kg^{-1} BW) despite conflating the male and female rats. HPLC analysis indicated the presence of three alkaloids amines—piperamine, αβ-dihydrowasnine, and isobutyl-(*EE*)-2,4-decadienamide. The study suggests that the extract contains substances which interfere with conception in mice.

Effect on smooth muscle

Udoh *et al.* (1996) evaluated the effect of leaf and seed extracts on smooth muscle. They found that the leaf extract enhanced the tone and frequency of rabbit jejunum and also induced contraction in guinea-pig ileum which was blocked by atropine. Furthermore, seed extract relaxed rabbit jejunum, whereas seed and leaf extract had a stimulant effect on rat uterine muscle.

Antioxidant property

Antioxidants are enzymes or non-enzyme molecules that help to defend cells from the deleterious effects of reactive oxygen species (ROS) such as superoxide and hydroxyl radicals and peroxides that typically destroy biomembranes (Jayachitra and Krithiga, 2010; Onoja *et al.*, 2014). Overproduction of ROS in disease conditions—such as diabetes, Alzheimer's disease, cancer, neurodegenerative diseases, exposure to bacterial or viral toxins, and radiations—generally exacerbate pathological state and often require medical interventions that stimulate the production of antioxidant molecules and/or positively modulate antioxidant enzymes. Several plant secondary metabolites have been shown to exert antioxidant activities through various mechanisms (Khalaf *et al.*, 2008; Patel *et al.*, 2010).

Antioxidant, hepatoprotective, and hematological effects

Uhegbu *et al.* (2015) studied the effect of aqueous seed extract at 10 and 20 mg kg^{-1} in rat liver. It was observed that the extract significantly decreased the liver enzymes ALT and ALP in the rat. They suggested that the seed extract might possess hepatoprotective ability. There was also a significant decrease in antioxidant enzyme—catalase and glutathione peroxidase—which points to the fact that they were being used up. This suggests that the extract may also offer protection against oxidative stress. There was an increase in red and white blood cells which might be due the nature and quantity of the protein content of *P. guineense*. The increase in WBC gives an index of immune function. The plant seeds are rich in phytonutrients, vitamins, and minerals which enhance synthesis of red and white blood cells (Okigbo and Igwe, 2007). Etim *et al.* (2013) also reported significant antioxidant activity of *P. guineense* due to its free radical scavenging potential.

Antimicrobial activity

The antimicrobial and antifungal activity was studied by Anyawu and Nwosu (2014). The effect of the ethanol and aqueous extracts of the leaves of the plant against the bacteria—*S. aureus*, *E. coli*, *P. aeruginosa*, *B. subtilis*; and the fungi—*C. albicans* and *S. cerevisiae*—using agar well diffusion method indicated that the ethanol extract showed the greatest antimicrobial sensitivity. The antimicrobial and antifungal activities were also investigated and validated by Ekanem and Obiekezie (2000). The antimicrobial activity against *Streptococcus faecalis* of cold and hot macerated aqueous, and ethanol extracts of *P. guineense* was also reported by Okigbo and Igwe (2007).

Effect on resistant strain of *E. coli*

Omonigbehin *et al.* (2013) investigated the susceptibility of enterohemorrhagic *E. coli* strain (O157:H7) isolates to conventional drugs and the extract of *Piper guineense* using agar diffusion method. They found that at MIC (200 mg ml^{-1}) and MBC (400 mg ml^{-1}), 63.64% of the isolates were resistant to the conventional antibiotics, whereas the *P. guineense* extract exhibited inhibition against all the isolates (100%).

Anti-parasitic activity

The *in vivo* antiplasmodial effect of the crude ethanol extract of *P. guineense* against rodent malaria parasite *P. berghei* was investigated by Kabiru *et al.* (2016), and they reported a reduction in parasitemia in a dose-dependent pattern. They also reported the analgesic effect which was dose-dependent but was not as effective as aspirin, the positive control drug.

Molluscidal activity

The molluscidal effect of the crude ethanol and hot-water fruit extract of *P. guineense* against *Biomphalaria pfeifferi*, the snail intermediate host of *Schistocoma mansoni*, which causes intestinal schitosomiasis, have been reported. The crude ethanol and hot-water extracts showed a significant toxic effect on the organism and significant decrease in oviposition rate (Ukwandu *et al.*, 2011).

Table 1. Overview of the phytochemistry and biological activity of *P. guineense*.

Author(s)	Plant part	Phytochemistry	Biological activity				
			Reproductive effect	Antioxidant properties	Antimicrobial/ antiparasitic activity activity	Anticancer	Insecticidal
Chiwendu *et al.* (2016)	Seeds	Alkaloids—0.86, saponins—1.87, tannins—1.19, flavonoids—0.72, polyphe-nols—0.66, and HCN—8.87%					
Klin-Kabari *et al.*, (2011)	Essential oil from seed	Dillapiol, piperine (5–8%), elemicine, myristicine (10%), and safrole					
Issac (2012)	Seeds	β-caryophyllene					
Ekanem *et al.* (2010)	Ethanol extract	Piperamine, αβ-dihydrowasnine, and isobutyl-(EE)-2,4-decadienamide	Contraceptive effect in female rats				
Udoh *et al.*, (1999)	Aqueous leaf extract		Uterotonic activity in female rats				
Mbongue *et al.* (2005)	Aqueous extract of seeds		Reduced fecundity in male rats				
Uhegbu *et al.* (2015); Etim *et al.* (2013)	Aqueous extract of seeds			Reported antioxidant activities in rats			
Anyawu and Nwosu (2014)	Ethanol/aqueous extract of leaves				Bactericidal and fungicidal properties		
Omonigbehin *et al.* (2013)	Ethanol extract of seed				Inhibited resistant strain of *E. coli* at MIC (200 mg ml^{-1}) and MBC (400 mg ml^{-1})		
Kabiru *et al.* (2016)					Reduced *P. berghei* load in rat models		
Iweala *et al.* (2015)	Dichloromethane leaf extract					Active against human myeloid leukaemia (HL—60) cell line with an IC_{50} of 3.60 µg ml^{-1}	
Olawuyi *et al.* (2013)	Aqueous seed extract						Prevented insect attack on *P. guineense*—treated *A. viridis* seedling

Ogbunugafor *et al.*, 2017.

Cancer

Cancer is increasingly becoming an important health concern in Africa (Kuete *et al.*, 2011; 2014) as a result of adoption of life-styles resulting from economic developments such as smoking, inexertion, and unhealthy diet (WHO, 2008). Incidentally too, the skewed attention paid to communicable diseases as against non-communicable ones in developing countries has, insidiously, further confounded the cancer blight in Africa (Cancer in Africa, 2012).

Anticancer properties

The anticancer activity of dichloromethane leaf extract of *P. guineense* against human myeloid leukemia (HL-60) cell line with an IC_{50} of 3.60 µg ml^{-1} was reported by Iweala *et al.* (2015). Investigation of the hexane extract of the leaves and seeds showed varying toxicity against human myeloid leukemia (HL-60), human hepatocellular carcinoma (SMMC-7721), human lung carcinoma (A-549), human breast adenocarcinoma (MFC-7), and colon cancer (SW-480) (Iweala *et al.*, 2015).

Table 2. Overview of the phytochemistry and biological activity of *A. melegueta*.

Author(s)	Plant part	Phytochemistry	Nutritional profile	Biological activity			
				Antioxidant properties	Anticancer	Anti-diabetic/ hypoglycemic properties	Hepatic/ toxicological properties
Echo *et al.* (2012)	Ethanolic seed extract	(mg 100 g^{-1}) Alkaloids—2.17 ± 0.29, flavonoids—2.03 ± 0.07, phenols—35.40 ± 0.76, cardiac glycosides—58.67 ± 1.1					
Alaje *et al.* (2014)	Aqueous seed extract	(mg/100g) Alkaloids—0.30 ± 0.20, flavonoids—6.10 ± 0.10, phenols—0.09 ± 0.10, tannins—0.41 ± 0.11, saponins—1.23 ± 0.30	Proximate content (%): Moisture—13.66 ± 0.18, crude protein—7.20 ± 0.05, fat—2.60 ± 0.31, crude fibre—5.54 ± 0.13, ash—2.50 ± 0.08, carbohydrate—31.50 ± 0.0				
Dike and Ahamefula (2012)	Aqueous seed extract	(mg/100 g) alkaloids—2.79, flavonoids—8.95, tannins—0.435, saponin—0.52	Proximate content (%): moisture—5.62, crude protein—8.75, fat—1.00, crude fibre—7.04, ash—8.00, carbohydrate—70.59				
Owokotomo *et al.* (2013)	Essential oil of seeds and leaves	GC-MS analysis indicated presence of β-caryophyllene (32.50) and α-caryophyllene (48.78) as major constituents: myrtenyl acaetate (29.06) and iso-limonene (19.47) were abundant in leaves					
Onoja *et al.* (2014)	Methanolic seed extract			25–400 μg ml^{-1} produced concentration-dependent decrease in DPPH oxidation strength in a photometric assay			
Umukoro and Ashorobi (2008)	Aqueous seed extract			Reduced RBC lysis and MDA production in rats challenged with oxidative stress			
Dibwe *et al.* (2015)	Chloroform extract of root				Killed pancreatic cancer cells (PANC-1) *in vitro*; arctigenin and buplerol were implicated to be the bioactive agent		
Kuete *et al.* (2011)					Killed pancreatic cancer (MiaPaca-2) and leukemia (CCRF-CEM) cell lines		

Table 2. Continued

Author(s)	Plant part	Phytochemistry	Nutritional profile	Biological activity			
				Antioxidant properties	Anticancer	Anti-diabetic/ hypoglycemic properties	Hepatic/ toxicological properties
Adefegha *et al.* (2016)	Seed oil					Inhibited α-amylase and α-glucosidase activities *in vitro* with EC_{50} values of 139 µl ml^{-1} and 91 µl ml^{-1}, respectively	
Mohammed *et al.* (2015)	Methanol extract					Reported improved insulin release and β-cells of pancreas in STZ-induced T2D rats exposed to 150–300 mg/kg extract	
Mojekwu *et al.* (2011); Adesokan *et al.* (2011)	Seed aqueous extract					Decreased blood glucose level in alloxan-induced diabetic rats in dose-dependent manner	
El-Halawany *et al.* (2014)	Methanol and chloroform extracts of seeds						Reversed CCL_4-induced hepatic damage
Nwozo and Oyinloye (2011)	Aqueous seed extract						Reversed ALT, TG, and AST elevation induced by alcohol
Ilic *et al.* (2010)	Ethanol seed extract						Elevation of liver enzymes-AST, ALT, and alkaline phosphatase in rats at 450–1500 mg kg^{-1} BW

Ogbunugafor *et al.*, 2017.

Weight control property

Mba (1994) reported the weight control potential of leaves of *Piper guineense* in rats.

Insecticidal activity

Olawuyi *et al.* (2013) investigated the insect pest control activity of aqueous extract of the seed of *P. guineense*. The extract was applied at varying concentration once weekly for 4 weeks, to germinating seeds of *Amaranthus viridis*. It was observed that the *P. guineense*-treated plants were not attacked by insect pest, whereas the untreated control plants were attacked. The authors summarized that seeds could control pest of *A. virdis* during cultivation.

Animal production

The health concerns due to side effects associated with the use of antibiotics to improve animal production have created the need for safer means of achieving the same goal (Danoghue, 2003). These side effects have led to the ban on the use of antibiotic in livestock production globally (Nweze and Nwakwagu, 2010). These reasons have generated interest in herbs and spices as supplements in animal rations (Odoemelam *et al.*, 2013). The consequence is that up to one-third of the world's swine and chicken rations in Europe now use herbs and spices mixtures to accelerate growth and maintain health (Odoemelam *et al.*, 2013).

Bioremediation ability

Oil pollution and environmental degradation due to crude oil prospecting activities of the Niger Delta region of Nigeria have warranted the massive cleanup exercise of the area at a huge cost to the government. Therefore, cheaper and alternative ways using plants—phytoremediation—is a desirable option. Phytoremediation effect of *Piper guineense* on the levels of polycyclic aromatic hydrocarbons (PAHs) on artificial crude oil polluted germinating *T. occidentalis*

Table 3. Overview of the phytochemistry and biological activity of *T. tetraptera.*

Author(s)	Plant part	Phytochemistry	Nutritional profile	Biological activity		
				Anti-inflammatory	Antidiabetic/hypoglycaemic activity	Antimicrobial activities
Ebana *et al.* (2016)	Aqueous and ethanol extracts of *T. tetraptera* fruits	Contained alkaloids, glycoside, saponins, flavonids, polyphenol, phlobatannins, anthraquinones, and hydroxymethyl anthraquinones				
Achi (2006)	Ethanol extract of pods	IR and NMR analysis revealed tannins and cinnamic acids				
Ekwenye and Okorie (2010)	Extract of pods	Quantitative analysis indicated (%): alkaloids 0.54, saponins 1.2, tannin 0.3, flavonoid 0.8, phenol 0.42%				
Adesina (2016)	Dry fruits	(mg 100 g^{-1}) polyphenol (38.05–2907.15), flavonoid (10.30–410.75), saponin (60.80–953.40), tannin (135.50–1097.50), and phytate (1021.00–5170.00)				
Udourioh and Etokudoh (2014)	Essential oil of seed	GC-MS analysis indicated oil to be rich in: acetic acid (34.59%), 2-hydroxy-3-butanone (18.25%), butanoic acid (8.35%), 2-methyl butanoic acid (7.58%), 2-methyl butanol (7.45%), butanol (4.30%), 2-methyl butenoic acid (3.65%), and nerol (3.25%)				
Okwu (2003)	Seeds		Crude protein (7.44–17.5%) crude lipid (4.98–20.24%), and crude fiber (17–20.24%)			
Abil and Elegalam (2007)	Dried fruit		Ca, P, K, Mg, Zn, and Fe, with Zn (10.59 mg 100 g^{-1}) and Fe (12.02 mg 100 g^{-1}) being most abundant			
Ojewole and Adewunmi (2004); Adesina *et al.* (2016)	Aqueous extract of the fruit			Anti-inflammatory activity in rays attributed to the hentriacontane content		
Adesina *et al.* (2016)	Aqueous extract of fruit				Reduced blood glucose level in STZ-induced diabetic rats	

Table 3. Continued

Author(s)	Plant part	Phytochemistry	Nutritional profile	Biological activity		
				Anti-inflammatory	Antidiabetic/hypoglycaemic activity	Antimicrobial activities
Atawodi *et al.* (2014)	Methanol extract				Reduced fasting blood glucose level (30.15%) in diabetic rats	
Komlaga (2004)	Methanol extract of fruit				Administered doses of between 1000–4000 mg kg^{-1} reduced blood glucose levels in diabetic rats	
Achi (2006), Ekwenye and Okorie (2010), Aboaba (2011), and Oguoma *et al.* (2015)	Seed extract					Bactericidal/bacteriostatic against *Salmonella typhi*, *Bacillus subtilis*, *P. aeruginosa*, *Escherichia coli*, *Shigella* spp., and *Staphylococcus aureus*. With MIC range of 250–500 μg ml^{-1}
Igwe and Akabuike (2016)	Aqueous seed extract					Inhibitory activity against *A. niger and P. notatum*
Köhler (2002); Okokon *et al.* (2007)	Ethanolic fruit extract					Schizonticidal and Antiplasmodial activity

Ogbunugafor *et al.*, 2017.

was evaluated using gas chromatography (GC); Etim *et al.* (2014) showed that the plant could be good for phytoremediation of phenanthrene, chrysene benzo(b)fluoranthene, dibenzo(a,b)athracene, and indeno(1,2,3) pyrene because they were found in significantly lower quantity in plants grown in vessels bioremediated with *P. guineense* and *A. indica*, and the combination of both.

Aframomum melegueta K. Schum

Description

Aframomum melegueta K. Schum belongs to the ginger family (Zingiberaceae) and is colloquially called grains of paradise or alligator pepper (Nwaehujor *et al.*, 2014). It is variously known locally as *ose oji* in Igbo, ataare in Yoruba, and *cittáá* in Hausa of Nigeria (Odugbemi, 2008). The plant is a perennial deciduous herb native to the tropics and grows mainly on the swampy habitats of the West African coast, characterized by a leafy stem that may be up to 1.5 m high. It produces trumpet-shaped, purple-colored flowers which develop into 5 to 7 long pods with each containing as many as 300 reddish-brown seeds (Dalziel, 1937).

Folkloric and ethnomedical uses

The seed of *A. melegueta* is used in different African cultures as a spice, medicine, or for other preternatural roles. In folk medicine, the seeds are employed as a local remedy for stomach ache, snakebite, diarrhea, cardiovascular diseases, diabetes, and inflammation (Ilic *et al.*, 2010). In the Igbo culture of Eastern Nigeria, alligator pepper is chewed alongside kola nut where the hot spicy taste of the former attenuates the astringent taste of the latter. The seeds are also used in preparing yam pottage for new mothers to enhance appetite and reduce the risk of puerperal infections in most parts of Southern Nigeria (Dike and Ahamefula, 2012).

Phytochemistry

The seeds of *A. melegueta* have been variously reported to be particularly rich in carbohydrates, crude fibre, and bulk minerals (Dike and Ahamefula, 2012; Echo *et al.*, 2012; Alaje *et al.*, 2014), indicating it to be of good nutritional quality, and hence justifying its incorporation into diet. NMR and GC-MS analyses of the chloroform extract of the seeds and essential oils from various plant parts, respectively (Owokotomo *et al.*, 2013; El-Halawany *et al.*, 2014), show the plant to be rich in secondary metabolites such as modified gingerols, paradols, shogaols, and diarylheptanoids. These metabolites account for some of peppery taste of the seeds (Ajaiyeoba and Ekundayo, 1999).

Biological Activities

Antioxidant properties

Onoja *et al.* (2014) showed *A. melegueta* to exhibit significant antioxidant activity when screened *in vivo* and *in vitro*. The extract (25–400 μg ml^{-1}) produced concentration-dependent decrease in 2,2-diphenylpicryhydrazine (DPPH) oxidation strength in a photometric assay. In the *in vivo* study, 400 mg kg^{-1} BW of the methanolic extract significantly boosted serum catalase and superoxide dismutase activities in rat. In another study (Umukoro and Ashorobi, 2008), testing its antioxidant and membrane stabilizing effect on rat RBCs exposed to phenylhydrazine, the aqueous seed extract of *A. melegueta,* was able to reduce lysis and production of malondialdehyde (MDA) in the sampled RBC in a dose-dependent manner; further suggesting its strong antioxidant capacity. Malondialdehyde is an efficient marker for oxidative stress as it is produced by oxidation of polyunsaturated fatty acids (PUFAs) by ROS (Benoist d'Azy, 2016).

Work on the essential oils obtained via hydrodistillation has also shown good antioxidant characteristics. In one study (Adefegha, *et al*., 2016), it was shown that *A. melegueta* seeds had the ability to inhibit the production of MDA induced by sodium nitroprusside (SNP) and Fe^{2+} in rat pancreas and heart tissues at EC_{50} of 131.76 and 111.23 µl ml^{-1}, respectively.

Cancer

Several species of *Afromomum* (*arundinaceum*, *melegueta*, *polyanthum*) harvested from the West African sub-region have been demonstrated to show some form of antineoplastic property (Kuete *et al*., 2011, 2014). For *A. melegueta*, work by Dibwe *et al.* (2015) on the plants harvested from the Democratic Republic of Congo (DRC) found that chloroform extract of *A. melegueta* root killed pancreatic cancer cell lines (PANC-1) preferentially in a nutrient-deprived medium. The antineoplatic property was attributed to two compounds—arctigenin and buplerol—fractionated from the root extract with IC_{50} of 0.5 and 8.4 µg ml^{-1}, respectively.

Also, work by Kuete *et al.* (2011) on the methanol extract of *A. melegueta* showed the seeds to possess significant inhibitory activities (IC_{50} value above 10 µg ml^{-1}) on human pancreatic cancer (MiaPaca-2) and leukemia (CCRF-CEM) cell lines, and significant activity of the crude extract on multidrug-resistant variant (CEM/ADR5000) of leukemia cells (IC_{50}: 7.08 µg ml^{-1}).

The research done on the chemotherapeutic potential of *A. melegueta* are yet few but are generally promising.

Anti-diabetic/hypoglycemic properties

The incidence of diabetes continues to rise in Africa, especially in urban areas where diet has become increasingly unwholesome (Kengne *et al*., 2005).

The use of *A. melegueta* in folk medicine in treating diabetes has a long and widespread history in West Africa (Ogbera and Ekpebegh, 2014). There has been a modest scientific effort to validate the folkloric use of this plant in treating diabetes with promising findings.

In a study by Adefegha *et al.* (2016), the oil from *A. melegueta* was shown to inhibit α-amylase and α-glucosidase activities *in vitro* with EC_{50} values of 139 and 91 µl ml^{-1}, respectively. In yet another research effort (Mohammed *et al*., 2015), the ethanolic extract of *A. melegueta* seeds exhibited significant ability to inhibit α-amyalse (EC_{50} 0.62 mg/ml) and α-glucosidase (EC_{50} 0.06 mg/ml) in Wistar rats. A finer resolution of the extract, employing the ethylacetate fraction on streptozotocin-induced type 2 diabetic rats, showed a reversal of diabetes symptoms when treated with 150–300 mg kg^{-1} BW of the extract. Remarkably, the extract led to pronounced amelioration of pancreatic β-cell dysfunction by reversing pathological changes in islets and β-cells (HOMA-β), while also increasing serum insulin levels.

Several other studies further reinforce the antidiabetic activity of *A. melegueta*. Mojekwu *et al.* (2011) reported that the aqueous extract (50–200 mg kg^{-1}) of the seeds reduced blood glucose levels in alloxan-induced diabetic rats in a dose-dependent manner; with the upper concentration (200 mg kg^{-1}) depressing sugar levels from 115.66 to 48 mg dl^{-1} within a 14-day window period.

In another study on the hypoglycemic potential (Adesokan *et al.*, 2016), the aqueous extract of the seed significantly reduced the blood glucose levels in alloxan-induced diabetic rats from 243 to 138 mg dl^{-1} with repeated daily oral administration of 200 mg kg^{-1} BW of the extract.

Although these reports are clearly indicative of an antidiabetic or hypoglycemic potential, there is still need to understand the mechanism of action of the plant especially how it induces reversal of pancreatic lesion, and hence increasing insulin production in otherwise hypoinsulinemic animal models.

Hepatic/toxicological properties

A major hindrance to the development of ethnomedicine in Africa is the poor toxicological profiling of plant materials used as nutraceuticals. However, recent research effort on African plants of medical importance is gradually improving knowledge gaps. El-Halawany *et al.* (2014) reported a significant reversal of CCL_4-induced hepatic damage by the methanol and chloroform extracts of *A. melegueta* seeds. In their study, ALT levels were decreased from chronically high levels induced by CCL_4 intoxication, whereas the level of reduced glutathione was increased from a depressed level induced by the aforementioned intoxicant.

In a related study (Nwozo and Oyinloye, 2011), hepatic aberration—as noted by increase in ALT, AST, and triglyceride (TG) levels—induced by chronic exposure to alcohol (4.8 g kg^{-1} BW) was attenuated by oral administration of *A. melegueta* seed extract to Wistar rats.

These results, however, contradict findings of related researches. Nwaehujor *et al.* (2014) observed perturbation of liver marker enzymes (alanine aminotransferase (ALT), aspertate aminotransferase (AST), and alkaline phosphatase (ALP)) in Sprague-Dawley rats exposed to a sublethal dose (300 mg kg^{-1} BW) of methanol extract of *A. melegueta* seed administered orally for 21 days. ALT level was markedly elevated (55.8 µl^{-1} as against the control value of 32.2 µl^{-1}) after 21 days.

In another effort (Ilic *et al*., 2010), a 28-day subchronic toxicity study in male and female Sprague-Dawley rats conducted using ethanolic extract of the seeds of *A. melegueta* resulted in dose-related increase in liver enzymes in the experimental rats dosed with 450 and 1500 mg kg^{-1} BW. There was a corresponding increase in alkaline phosphatase with no signs of steatosis or cirrhosis. Clearly, a pattern emerges from the works considered in this review. The extracts of *A. melegueta* seeds seem to be harmless (even beneficial to the liver) at low concentrations (<200 mg kg^{-1} BW) but may induced toxicity at concentrations above 300 mg kg^{-1} BW, in rats.

Other miscellaneous pharmacological properties

Anti-inflammatory properties

The seeds of *A. melegueta* has been reported to possess anti-inflammatory properties by inhibiting cyclooxygenase 2 (COX-2), an enzyme involved in generating pro-inflammatory prostaglandins, in rat paw edema model by 49% at concentration of 1000 mg kg^{-1} BW. 6-Paradol, one of the several gingerols obtained by bioactivity-guided fractionation using methanol, was implicated as the active anti-inflammatory ingredient (Ilic *et al*., 2014).

Aphrodisiac properties

Administration of 115 mg kg^{-1} of *A. melegueta* daily for 8 days led to an increase in the penile erection index (PEI), frequency of genital grooming and genital sniffing, and an increase in mounting frequency by 54% as reported by Kamtchouing *et al.* (2002), in male Wistar rats.

Antidiarrhoeal

Pharmacological evaluation of the effects of intraperitoneal injection of aqueous seed extract of *A. melegueta* on diarrhoea, intestinal fluid secretion, and gastrointestinal transit time induced by castor oil in rodents revealed that extract (50–200 mg kg^{-1}) produced a significant inhibition of castor oil–induced diarrhoea in rats with mechanistic studies suggesting its antidiarrhoeal activity stems from its ability to inhibit prostaglandin formation (Umukoro and Ashorobi, 2005).

Neuronal activity

Aframomum melegueta extract has been shown to moderately inhibit acetylcholinesterase activity with an IC_{50} of 373.33 µg ml^{-1} (Adefegha and Oboh, 2012).

Tetrapleura tetraptera Schumach and Thonn Taub (Mimosaceae)

Description

Tetrapleura tetraptera Schumach and Thonn Taub (Mimosaceae), Yoruba name *aridan*, *oshogisha in Igbo* is a single-stemmed deciduous plant that grows on the fringe of the West and Central African rainforest zone. The fruit has four winged pods and appears green when tender but shiny, glabrous, dark-purple-brown when mature and ripened (Uyom *et al.*, 2013; Adesina *et al.*, 2016). The fruit consists of a fleshy pulp with small, brownish-black seeds and possesses a characteristically pungent aromatic odor, which contributes to its insect-repellent property (Adetunji, 2007). Two of the fruit's wings are woody, whereas the other two are filled with soft, oily, and aromatic sugary pulp. The seeds, which rattle in the pods, are small, black, hard, flat, about 8-mm long, embedded in the body of the pod, which does not split open.

Folkloric and ethnomedical uses

Orwa *et al.* (2009) noted that every part of the plant has found use in one industry or the other. The fruit pulp is rich in sugars and may be used in flavouring food; the fairly hard heartwood and white sapwood are used in timber, its tannin is used as a dye and in medicine, extracts of the leaves, bark, roots, and kernel has been exploited as medicines. Also, the fruit and flowers are used as perfumes (Ngassoum *et al.*, 2001; Adetunji, 2007).

Phytochemical screening

Ebana *et al.* (2016) examined the phytochemical content of aqueous and ethanol extracts of *T. tetraptera* fruits and reported that they contained alkaloids, glycoside, saponins, flavonoids, reducing compounds, polyphenol, phlobatannins, anthraquinones, and hydroxymethyl anthraquinones but lacked saponins and tannins. Glycosides, reducing compounds, and polyphenol are the most abundant of phytochemicals in the ethanol extract according to the study. Similarly, the pods extracted with cold water and ethanol were screened for the presence of alkaloids, glycosides, tannins, saponins, and anthraquinones (Achi, 2006). Using spectroscopic methods including IR and NMR, their analysis of the ethanol extracts afforded active compounds which were characterized as tannins, cinnamic acids, and carbohydrates.

Quantitative analysis by Ekwenye and Okorie (2010) indicated that alkaloids and saponins were present in the pod at 0.54% and 1.28%, respectively, and reported other phytochemical contents as tannin 0.36%, flavonoid 0.84%, and phenol 0.42%. Adesina (2016) gave a summary of the quantities of the phytochemical constituents of the fruits (mg/100 g dry weight of fruit) as follows: total polyphenol (38.05–2907.15), flavonoid (10.30–410.75), saponin (60.80–953.40), tannin (135.50–1097.50), and phytate (1021.00–5170.00).

Essential oil

Udourioh and Etokudoh (2014) analyzed the essential oil and fatty acids composition of the dry fruits of *T. tetraptera* using GC/MS and characterized 44 compounds representing 98.5% of the oil. The oil was dominated by acetic acid (34.59%), 2-hydroxy-3-butanone (18.25%), butanoic acid (8.35%), 2-methyl butanoic acid (7.58%), 2-methyl butanol (7.45%), butanol (4.30%), 2-methyl butenoic acid (3.65%), and Nerol (3.25%).

The fatty acid content had palmitic acid as the highest (49.44%), and stearic acid as the least (3.20%), while the short chain fatty acids; omega-6 and omega-3 constituting 27% and omega-9 (20%), respectively. Bouba *et al.* (2016) also noted that it is one of the spices that contain large amounts of the essential (ω-3) fatty acids.

Nutritional profile

Proximate analysis of the plant indicates that it has crude protein, fiber, lipid, and carbohydrates. It has appreciable quantity of crude protein (7.44%–17.5%), crude lipid (4.98%–20.24%), and crude fiber (17%–20.24%; Okwu, 2003). After investigating the mineral content of the dried fruit, Abil and Elegalam (2007) noted that the fruits of *T. tetraptera* contained Ca, P, K, Mg, Zn, and Fe with Zn (10.59 mg 100 g^{-1}) and Fe (12.02 mg 100 g^{-1}) being appreciably higher than the other bulk elements. There was a discrepancy in ash content, however, as reported by Abil and Elegalam (2007) and Udourioh and Etokudoh (2014). While the former reported 9%, the latter reported 3.4% ash content.

Biological activities

The extracts and some of the isolated compounds showed sedative, hypotensive, molluscicidal, CNS depressant, anti-inflammatory, antimicrobial, wound-healing, contraceptive, analgesic, hypoglycemic, antioxidant, hypolipidemic, antimalarial, muscle-relaxant, anticonvulsant, hypothermic, and anxiolytic effects in experimental animals (Adesina, 2016).

Anti-inflammatory activity

Ojewole and Adewunmi (2004) reported that the aqueous extract of the fruit showed anti-inflammatory activity in egg albumin-induced pallet edema in rats. The anti-inflammatory activity of *T. tetraptera* is linked to the hentriacontane compound it contains (Adesina *et al.*, 2016).

Antidiabetic/hypoglycaemic activity

Adesina *et al.* (2016) investigated the effect of the aqueous extract of the plant on streptozotocin (STZ)-induced diabetes mellitus in rats. They found that the extract significantly decreased blood glucose level in the animals. Atawodi *et al.* (2014) reported that the methanolic extract of *T. tetraptera* leaves exhibited a significant percentage change (30.15%) in fasting blood sugar when compared to diabetic rat (0.59%) between a 7-day period. The extract also ameliorated the complications associated with diabetes in the rats such as oxidative stress and disorders in lipid metabolism. Komlaga (2004) reported the biphasic effect of the ethanolic extract of the fruit in rats at administered doses of between 1000 and 4000 mg kg^{-1} which exhibited a significant glucose lowering effect than the standard drug, glibenclamide.

Analgesic and anticonvulsant properties

T. tetraptera fruit's aqueous extract produced dose-dependent, analgesic effects against thermally and chemically induced pain in mice. Compared to the standard anticonvulsant agents (phenobarbitone and diazepam), the aqueous fruit extract delayed the onset of, and antagonized pentylenetetrazole (PTZ)-induced seizures. The aqueous extract of the fruit profoundly antagonized picrotoxin (PCT)-induced seizures, but only partially and weakly antagonized bicuculline (BCL)-induced seizures (Ojewole, 2005).

Antimicrobial activities

Several authors, e.g. Achi (2006), Ekwenye and Okorie (2010), Aboaba 2011, and Oguoma *et al.* (2015), have substantiated the antibacterial activity of the fruit of *T. tetraptera* and found it effective against common human pathogens *viz Salmonella typhi*, *Bacillus subtilis*, *P. aeruginosa Escherichia coli*, *Shigella* spp., and *Staphylococcus aureus*. Minimum inhibitory concentrations of the extract ranged from 250 µg/ml for *E. coli* to 500 µg/ml for *B. subtilis*.

Oguoma *et al.* (2015), however, observed reduced activity on *Shigella* spp. making the organism resistant to the extract.

The extract has activity against these fungi pathogens; *A. niger* and *P. notatum* (Igwe and Akabuike, 2016). The authors observed an increase in the antibacterial activity as extract concentration increased, suggesting that the extract could be useful in preventing the growth of pathogens in food. The ethanolic extract of the fruit exhibited better antibacterial activity than the aqueous extract and so was more potent against the test organisms. The hentriacontane content may be responsible for these actions as it exhibited antitubercular property according to Takahashi *et al.* (1995). However, there is a dearth of report on the antiviral activity of the plant.

Antimalarial activity

The extract of the fruit was investigated for antiplasmodial activity alongside different extracts from 10 other West African plants traditionally used against malaria in Ghana (Köhler, 2002). The extracts were tested against both the chloroquine-sensitive strain and the chloroquine-resistant clone of *Plasmodium falciparum*. The ethanolic fruit extract was also evaluated for its antiplasmodial activity *in vivo* by Okokon *et al.* (2007). The study reported that the extract exhibited significant blood schizonticidal activity with a considerable mean survival time when compared with a standard antimalarial drug, chloroquine. It was noted that the extract from the fruit possessed significant antiplasmodial activity. This could be the reason why the plant has found importance locally in the management of malaria and other feverish conditions.

Molluscicidal activity

All parts of the plant possess molluscicidal activity and the activity has been linked to the presence of saponins (Adesina *et al.*, 2016). Various works (Adesina *et al.*, 1980; Schaufelberger and Hostettmann, 1983; Maillard, 1989) including toxicological evaluation confirmed the potential of this plant for the control of snails (mollusks) and by extension control of schistosomiasis.

Conclusion

Critical evaluation of the literature on the nutritional and medical properties of the spices considered (*Piper guineense*, *Aframomum melegueta*, and *Tetrapleura tetraptera*) inarguably show that they have tremendous health potential. Work on the chemotherapeutic potentials of the plants is worthy of note, especially considering the increased resistance by cancerous cells and pathogenic microbes to conventional drugs. The three spices also displayed remarkable hypoglycemic potential through lowering blood glucose in experimental rats. As diabetes morbidity and mortality is on the rise in sub-Saharan Africa (Azevedo and Alla, 2008), these spices may play a role in formulating the next-generation antidiabetics.

Although these spices show promises in disease therapy, a caveat must be noted; eulogizing their therapeutic potential may be yet premature. For various physiological reasons, experiments in human close relatives (rats or apes) do not often exhibit similar outcomes in man, with sometimes bewildering health results. As most of these results were extrapolated from animals, it is thus important to see, firsthand, the effect on humans. This will definitely warrant further controlled clinical trials using human subjects.

Another hurdle often encountered in nutraceutical research is the issue of 'therapeutic dosage'. As most spices are conventionally consumed in small (milligram quantities at most) as culinary additives for its organoleptic attributes. It is often a challenge to quantify the effective dose of these spices. Another issue is how to determine the mode of action deriving some of these therapeutic benefits from the plants at these sub-therapeutic doses. Although, the advent of high-throughput screening/isolation techniques have helped in isolating active ingredients that are essential to therapeutic function from herbs; yet, even this approach is fraught with challenges, as it is increasingly becoming clear to researchers that plant phytochemicals tend to exert better biological function when they act in synergistic manner with each other. The recent development of microbial resistance to artemisinin, the active ingredient in *Artemisia annua* is a ghoulish reminder of how isolating supposedly active ingredient could backfire.

Overall, the health promise of the three spices reviewed remains significant, and the experimental results surveyed are in support of the majority of the ethnomedical/folkloric uses of these spices.

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