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Review Article

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A review on chemical constituents of essential oils of *Aframomum* genus

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ABSTRACT

Aframomum K.Schum is a genus native to Africa belonging to Zingiberaceae. Members of genus *Aframomum* are the aromatic and perennial rhizomatous herbs. Many plant parts of *Aframomum* species contain essential oils, including fruits, seeds, leaves, stems, rhizomes, pods, husks, pericarps, limbos and leaf sheaths. The major constituents of *Aframomum* plants are mainly composed of sesquiterpene hydrocarbons, oxygenated monoterpenes, oxygenated sesquiterpenes and monoterpene hydrocarbons. The present work provides comprehensive information regarding the volatile components of various *Aframomum* species.

KEYWORDS: Essential oils, *Aframomum*, chemical components

INTRODUCTION

The Zingiberaceae family comprises over 1500 species belonging to 50 genera. Members on Zingiberaceae are rhizomatous herbs and widely found throughout tropical Africa, Asia, and tropical America (Kress *et al.*, 2002). Several plant part of Zingiberaceae species such as seeds leaves, rhizomes and fruits have been used to treat heal bruises, sore throat, improve digestion, treat cough, and scars (Jantan *et al.*, 2004). In addition, Zingiberaceae was considered as an important natural resources as it was raw material used in the production of medicines, spices, cosmetics and essential oil (Koga *et al.*, 2016) (Zahara *et al.* 2018). In particular, many reports showed that their essential oil and major chemical components such as terpenes, alcohols, ketones, flavonoids and phytoestrogens have many biological activitives (Zahara *et al.*, 2018).

Aframomum K.Schum, a genus with over 80 species belonging to the Zingiberaceae family, are widely distributed in West and Central Africa. They are the perennial and large plants reaching up 6 meters tall (Amadi *et al.*, 2016). In the terms of traditional medicine, members of *Aframomum* have been commonly used by African as a remedy for antidiarrhoea, laxatives, anthelmintics, fever management, toothache, inflammatory conditions, stomach ache, postpartum haemorrhage and a tonic for sexual stimulation (Duke, 2002). In addition, diterpenoids, sesquiterpenoids, arylalkanoids and flavonoids are known as major phytochemicals of *Aframomum* species (Amadi *et al.*, 2016). Several bioactivities of *Aframomum* plant, including antimicrobial, anticancer, antiplasmodial, antinociceptive, hepatoprotective and antiulcer activities have been reported by previous studies (El-Halawany *et al.*, 2014).

Aframomum genus includes aromatic and perennial rhizomatous plants. The essential oils isolated from many plant parts of *Aframomum* species such as seeds, fruits, stems, rhizomes, leaves, pods, pericarps, husks, limbos and leaf sheaths possess some bioactive compounds. These components belong to different chemical groups such as oxygenated monoterpenes, monoterpene hydrocarbons, oxygenated sesquiterpenes, sesquiterpene hydrocarbons and non-terpenoid (Diomandé *et al.*, 2012; Nguikwie *et al.*, 2013; Huong *et al.*, 2017). However, there is a limitation in the overall review of the phytochemicals of essential oils obtained from *Aframomum* plants. Therefore, the main focus of the present review gives an overview of the chemical profiles and bioactivities of the essential oils isolated from the *Aframomum* species.

Volatile Compounds of *Aframomum* spp.

Generally, the volatile compounds of *Aframomum* spp. were identified by Gas Chromatography Mass Spectrometry. The plant parts which studies focused on many materials such as fruits, seeds, leaves, stems, rhizomes, pods, husks, pericarps, limbos and leaf sheaths. The major volatile compounds of the *Aframomum* spp. isolated from various plant parts were summarized in Table 1.

Table 1: Major components identifed from *Aframomum* essential oils

Scientific name	Origin	Part	Major Components	References
A. alboviolaceum	Contuboel, Guinea-Bissau	Rhizomes	Intermedeol (24.1%), carotol (8.3%), spathulenol (5.8%)	(Abreu & Noronha, 1997)
A. angustifolium	Madagascar	Seeds	β-pinene (24.8%), β-caryophyllene (17.8%), cis-pinocarvyl acetate (11.0%)	(Baser & Kürkçüoglu, 2001)
A. biauriculatum	Zambia	Leaves	β-pinene (58.5%), β-caryophyllene (14.2%), α-pinene (7.3%)	(Chisowa *et al.,* 1998)
A. biaurlculatum	Zambia	Rhizomes	β-pinene (23.8%), 1,8-cineole (22.5%), α-terpineol (5.0%)	(Chisowa *et al.,* 1998)
A. citratum	Bafoussam, Cameroon	Seeds	Geraniol (96.8%), linalool (1.3%)	(Dongmo *et al.,* 2019)
A. citratum	Bafoussam, Cameroon	Seeds	Geraniol (97.6 %), geranyl acetate (0.9%)	(Meffo *et al.,* 2019)
A. citratum	Yaounde, Cameroon	Leaves	β-pinene (62.0%), α-pinene (11.0%), β-caryophyllene (8.6%)	(Amvam *et al*., 2002)
A. citratum	Yaounde, Cameroon	Seeds	Geraniol (70.0%), linalool (15.0%), myrcene (1.5%)	(Amvam *et al.,* 2002)
A. citratum	Kribi, Cameroon	Seeds	Geraniol (68.9%) and linalool (15.1%), myrcene (1.5%)	(Chalchat *et al.,* 1997)
A. corrorima	Madagascar	Seeds	1,8-cineole (32.6 %), (*E*)-nerolidol (11.2%), α-terpinyl acetate (9.2%)	(Baser & Kürkçüoglu, 2001)
A. corrorima	southern Ethiopia	Leaves	β-caryophyllene (60.7%), β-pinene (11.9%), caryophyllene oxide (5.7%)	(Eyob *et al.,* 2008)
A. corrorima	southern Ethiopia	Rhizomes	γ-terpinene (21.8%), β-pinene (17.6%), β-caryophyllene (4.1%)	(Eyob *et al.,* 2008)
A. corrorima	southern Ethiopia	Pods	γ-terpinene (27.1%), β-pinene (15.4%), α-phllandrene (8.5%)	(Eyob *et al.,* 2007)
A. corrorima	southern Ethiopia	Seeds	1,8-cineole (39.3%), sabinene (10.4%), geraniol (6.8%)	(Eyob *et al.,* 2007)
A. corrorima	Merkato, Ethiopia	Seeds	1,8-cineole (44.3%), sabinene (17.3%), β-pinene (7.2%)	(Hymete *et al.,* 2006)
A. corrorima	Merkato, Ethiopia	Husks	*(E)*-nerolidol (17.2%), β-caryophyllene (9.7%), caryophyllene oxide (6.9%)	(Hymete *et al.,* 2006)
A. corrorima	Jeddah, Saudi Arabia	Seeds	1,8-cineole (51.8%), terpinen-4-ol (10.4%), limonene (5.4%)	(Noumi *et al*., 2018)
A. dalzielii	Fontem, Cameroon	Seeds	(*E*)-nerolidol (91.2%), 2-heptyl acetate (2.8%)	(Nguikwie *et al.,* 2013)
A. dalzielii	Fontem, Cameroon	Pericarps	β-pinene (43.3%), sabinene (14.2%), β-pinene (7.8%)	(Nguikwie *et al.,* 2013)
A. dalzielii	Fontem, Cameroon	Leaves	β-caryophyllene (81.4%), β-pinene (3.9%), caryophyllene oxide (3.3%)	(Nguikwie *et al.,* 2013)
A. dalzielii	Fontem, Cameroon	Rhizomes	β-pinene (37.9%), sabinene (22.9%), α-pinene (7.8%)	(Nguikwie *et al.,* 2013)
A. daniellii	Bafoussam, Cameroon	Seeds	1,8-cineole (48.8%), α-terpineol (21.7%), geraniol (10.5%)	(Dongmo *et al.,* 2019)
A. daniellii	Bafoussam, Cameroon	Seeds	1,8-cineole (51.5 %), α-terpineol (12.5%), β-pinene (8.5 %)	(Meffo *et al*., 2019)
A. daniellii	Bafoussam, Cameroon	Seeds	1,8-cineole (48.8%), β-pinene (11.2%), α-terpineol (10.8%)	(Pavela *et al.,* 2016)
A. daniellii	Bafoussam, Cameroon	Pericarps	β-pinene (17.6%), sabinene (11.7%), linalool (10.2%)	(Pavela *et al.,* 2016)
A. daniellii	Bafoussam, Cameroon	Leaves	sabinene (42.9%), (*E*)-caryophyllene (16.6%), β-pinene (5.8%)	(Pavela *et al.,* 2016)
A. daniellii	Bamougoum, Cameroon	Leaves	Sabinene (43.9%), (*E*)-caryophyllene (16.6%), β-pinene (5.8%)	(Kamte *et al.,* 2017)
A. daniellii	Balengou, Cameroon	Fruits	1,8-cineole (48.9%), limonene (12.8%), β-pinene (12.7%)	(Menut & Lamaty, 1991)
A. daniellii	Lagos State, Nigeria	Leaves	β-pinene (25.1%), limonene (13.8%), α-pinene (10.9%)	(Lawal *et al.,* 2017)
A. daniellii	Lagos State, Nigeria	Seeds	1,8-cineole (37.2%), linalool (31.3%), terpinen-4-o1 (7.2%)	(Lawal *et al.,* 2017)
A. daniellii	Rivers State, Nigeria	Seeds	1,8-cineole (50.95%), β-pinene (11.79%) α-terpineol (9.15%)	(Emmanuel *et al.,* 2020)
A. daniellii	Akwa Ibom, Nigeria	Leaves	β-pinene (47.55%), caryophyllene oxide (14.68%), β-caryophyllene (9.73)	(Essien *et al.,* 2017)
A. daniellii	Akwa Ibom, Nigeria	Stems	β-pinene (30.94%), α-phellandrene (10.12%), β-terpinene (8.98%)	(Essien *et al.,* 2017)
A. daniellii	Akwa Ibom, Nigeria	Seeds	1,8-cineole (53.44%), α-terpineol (12.23%), β-pinene (9.15%)	(Essien *et al.,* 2017)
A. daniellii	Akwa Ibom, Nigeria	Rhizomes	β-pinene (34.51%), α-phellandrene (8.77%), β-terpinene (9.81%)	(Essien *et al.,* 2017)
A. daniellii	Akwa Ibom, Nigeria	Pods	β-pinene (34.55%), α-phellandrene (12.26%), β-terpinene (13.49%)	(Essien *et al.,* 2017)
A. daniellii	Ibadan, Nigeria	Pods	1,8-cineole (56.16%), β-pinene (14.77%), α-terpineol (11.46%)	(Olosunde *et al.,* 2015)
A. daniellii	São Tomé and Príncipe	Fruits	1,8-cineole (34.4%), β-pinene (15.2%), α-terpineol (12.1%)	(Martins *et al.,* 2001)

(Contd...)

Table 1: *(Continued)*

Scientific name	Origin	Part	Major Components	References
A. daniellii	Akure, Nigeria	Seeds	Eugenol (51.14%), 1,8-cineole (10.93%), β-caryophyllene (5.11%)	(Adefegha *et al.,* 2017)
A. elliotti	Ivory Coast	Leaves	β-pinene (44.3%), β-caryophyllene (26.2%), α-pinene (5.1%)	(Diomandé *et al.,* 2012)
A. elliotti	Ivory Coast	Rhizomes	Linalool (45.3%), 1,8-cineole (17.1%), β-pinene (16.3%)	(Diomandé *et al.,* 2012)
A. exscapum	Assouba, Ivory Coast	Leaves	1,8-cineole (52.9%), (E)-Nerolidol (16.1%), α-Terpineol (6.3%)	(Muriel *et al.,* 2011)
A. exscapum	Malamalasso, Ivory Coast	Leaves	1,8-cineole (53.8%),α-Pinene (7.9%), Germacrene D (6.6%)	(Muriel *et al.,* 2011)
A. exscapum	Nianda North, Ivory Coast	Leaves	1,8-cineole (60%), Germacrene D (6.9%), α-Terpineol (6.7%)	(Muriel *et al.,* 2011)
A. exscapum	Nianda Sounth, Ivory Coast	Leaves	1,8-cineole (61.0%), Germacrene D (6.9%), β-Pinene (6.3%)	(Muriel *et al.,* 2011)
A. exscapum	Nianda East, Ivory Coast	Leaves	1,8-cineole, Germacrene D (7.3%), β-Pinene (6.4%)	(Muriel *et al.,* 2011)
A. geocarpum	Ivory Coast	Leaves	β-caryophyllene (58.1%), β-humulene (15.0%), β-pinene (11.3%)	(Diomandé *et al.,* 2012)
A. geocarpum	Ivory Coast	Rhizomes	β-pinene (22.7%), cyperene (11.8%), caryophyllene oxide (10.5%)	(Diomandé *et al.,* 2012)
A. giganteum	Africa Republic	Stems	Linalool (28.0%), linalyl acetate (11.5%),α-terpineol (5.5%)	(De Bernardi *et al.,* 1981)
A. giganteum	Gabon	Leaves	*cis*-pinocamphone (54.0%), *cis*-pinocamphone (10.1%), *trans*-verbenol (2.1%)	(Agnaniet *et al.,* 2004)
A. giganteum	Gabon	Rhizomes	caryophyllene oxide (30.4%), β-caryophyllene (10.5%), β-caryophylla-4(14),8(15)-dien-5-ol (4.6%)	(Agnaniet *et al.,* 2004)
A. giganteum	Congo Republic	Seeds	β-pinene (340.0g/kg), 1,8-cineol (170g/kg), β-selinene (230.0g/kg)	(Ngakegni *et al.,* 2013)
A. giganteum	Congo Republic	Husks	α-selinene (204.5g/kg), linalool (188.9g/kg), α-pinene (143.4g/kg)	(Ngakegni *et al.,* 2013)
A. hanburyi	*Yaounde,* Cameroon	Leaves	β-pinene (51.9%), α-pinene (8.5%), limonene (7.0%)	(Amvam *et al.,* 2002)
A. hanburyi	*Yaounde,* Cameroon	Seeds	(E,E)-farnesol (27.3%), linalool (19.0%), terpinolene (8.2%),	(Amvam *et al.,* 2002)
A. latifolium	Oyo State, Nigeria	Leaves	1,8- cineole (45.05%), β-pinene (20.97%), cyclofenchene (7.82)	(Olagoke & Amusat, 2019)
A. latifolium	Yamoussoukro, Ivory Coast	Leaves	β-pinene (51.6%) and β-caryophyllene (12.3%), sabinene (7.6%)	(Tia *et al.,* 2011)
A. letestuanum	Bamendjida, Cameroon	Seeds	*(E)*-nerolidol (88.0%), linalool (2.2%), humulene epoxide II (1.3%)	(Nguikwie *et al.,* 2013)
A. letestuanum	Bamendjida, Cameroon	Pericarps	β-pinene (38.5%), linalool (10.1%), caryophyllene oxide (8.9%)	(Nguikwie *et al.,* 2013)
A. letestuanum	Bamendjida, Cameroon	Leaves	caryophyllene oxide (23.7%), β-caryophyllene (18.4%), β-pinene (13.4%)	(Nguikwie *et al.,* 2013)
A. letestuanum	Bamendjida, Cameroon	Rhizomes	β-pinene (32.9%), cyperene (4.9%), β-pinene (5.9%)	(Nguikwie *et al.,* 2013)
A. letestuanum	Yaounde, Cameroon	Seeds	(*E*)-nerolido (67.0%), linalool (7.0%), (*E,E*)-farnesol (3.4%)	(Amvam *et al.,* 2002)
A. longiscapum	Ivory Coast	Leaves	β-pinene (42.6%), β-caryophyllene (25.4%), α-pinene (5.2%)	(Diomandé *et al.,* 2012)
A. longiscapum	Ivory Coast	Rhizomes	β-pinene (40.2%), linalool (27.4%), α-pinene (5.3%)	(Diomandé *et al.,* 2012)
A. melegueta	Ojo Lagos, Nigeria	Seeds	2-octyl acetate (60.4%), linalyl acetate (16.5%), α-humulene (6.0%)	(Lawal *et al.,* 2017)
A. melegueta	Ibadan, Nigeria	Seeds	β-humulene (60.9%), β-caryophyllene (21.7%), humulene oxide II (5.5%)	(Ajaiyeoba & Ekundayo, 1999)
A. melegueta	Central African Republic	Leaves	β-pinene (32.8%), β-caryophyllene (9.6%), β-humulene (6.7%),	(Lamaty *et al.,* 1993)
A. melegueta	Central African Republic	Seeds	β-pinene (37.0%), germacrene D (16.9%), β-caryophyllene (13.4%),	(Lamaty *et al.,* 1993)
A. melegueta	South West Nigeria	Leaves	Myrtenyl acetate (29.06%), isolimonene (19.47%), β-elemene (8.84%)	(Owokotomo, 2014)
A. melegueta	South West Nigeria	Stem	Caryophyllene oxide (19.70%), myrtenyl acetate (14.70%), β-eudesmene (10.83%)	(Owokotomo, 2014)
A. melegueta	South West Nigeria	Roots	Myrtenyl acetate (22.70%), pinocarvyl acetate (11.50%), cyperene (8.96%)	(Owokotomo, 2014)
A. melegueta	South West Nigeria	Seeds	β-caryophyllene (48.78%), β-caryophyllene (32.50%) and linalool (5.40%)	(Owokotomo, 2014)

(Contd...)

Table 1: *(Continued)*

Scientific name	Origin	Part	Major Components	References
A. melegueta	Bayelsa State, Nigeria.	Seeds	Carvone (13.47%), menthol (11.88%), methone (9.07%)	(Owokotomo, 2014)
A. melegueta	Akure, Nigeria	Leaves	Myrtenyl acetate (29.06%), limonene (19.45%), β-elemene (8.84%)	(Owokotomo, 2018)
A. melegueta	Akure, Nigeria	Stems	Caryophyllene oxide (19.7%), myrtenyl acetate (14.7%), β-eudesmene (10.83%)	(Owokotomo, 2018)
A. melegueta	Akure, Nigeria	Seeds	α-caryophyllene (48.78%), β-caryophyllene (32.5%)	(Owokotomo, 2018)
A. melegueta	Akure, Nigeria	Rhizomes	Myrtenyl acetate (22.7%), pinocarvyl acetate (11.5%), cyperene (8.96%)	(Owokotomo, 2018)
A. melegueta	Akure, Nigeria	Seeds	Eugenol (82.2%), α-caryophyllene, β-caryophyllene (3.27%)	(Adefegha *et al.,* 2017)
A. melegueta	Lagos State, Nigeria	Leaves	sabinene (35.9 %), α-pinene (15.0 %), β-caryophyllene (9.7 %)	(Lawal *et al.,* 2015)
A. melegueta	Foumbam, Cameroon	Fruits	1,8-cineole (58.5%), α-terpineol (19.4%), β-pinene (7.1%)	(Kamte *et al.,* 2017)
A. melegueta	Mbalmayo, Cameroon	Fruits	α-Humulene (48.9%), Humulene oxide II (26.4%), Caryophyllene oxide (17.9%)	(Menut & Lamaty, 1991)
A. pruinosum	Fontem, Cameroon	Seeds	(*E*)-nerolidol (95.1%), β-ocimene (1.6%), α-bisabolol (0.5%)	(Nguikwie *et al.,* 2013)
A. pruinosum	Fontem, Cameroon	Pericarps	β-pinene (29.0%), 1,8-cineole (1.4%), caryophyllene oxide (9.0%)	(Nguikwie *et al.,* 2013)
A. pruinosum	Fontem, Cameroon	Leaves	β-caryophyllene (47.7%), β-pinene (27.8%), caryophyllene oxide (6.2%)	(Nguikwie *et al.,* 2013)
A. pruinosum	Fontem, Cameroon	Rhizomes	β-pinene (34.3%), linalool (5.5%), cyperene (4.4%)	(Nguikwie *et al.,* 2013)
A. pruinosum	Yaounde, Cameroon	Leaves	β-pinene (31.4%), β-caryophyllene (25.8%), caryophyllene oxide (9.1%)	(Amvam *et al.,* 2002)
A. pruinosum	Yaounde, Cameroon	Seeds	(E)-nerolido (91.7%), β-ocimene (1.0%), linalool (0.9%)	(Amvam *et al.,* 2002)
A. pruinosum	Dshang, Cameroon	Leaves	β-pinene (31.4%), β-caryophyllene (25.8%), caryophyllene oxide (9.1%)	(Menut *et al.,* 1994)
A. pruinosum	Dshang, Cameroon	Seeds	(E)-nerolido (91.7%), β-ocimene (1.0%), linalool (0.9%)	(Menut *et al.,* 1994)
A. sanguineum	Bujumbura, Burundi	Seeds	1,8-cineole (38.5%), α-terpinyl acetate (9.6%), geranyl acetate (9.4%)	(Hari *et al.,* 1994)
A. sceptrum	Ivory Coast	Rhizomes	β-pinene (12.7%), caryophyllene oxide (10.0%), cyperene (6.0%)	(Cheikh-Ali *et al.,* 2011)
A. sceptrum	Ivory Coast	Leaves	β-pinene (15.1%), 1,8-cineole (12.1%), β-humulene (10.1%)	(Diomandé *et al.,* 2012)
A. sceptrum	Ivory Coast	Rhizomes	β-elemene (10.4%), β-pinene (7.8%), β-humulene (6.7%)	(Diomandé *et al.,* 2012)
A. sceptrum	Abomey calavi, Benin	Limbos	β-caryophyllene (33.4%), β-pinene (28.4%), β-humulene (10.6%)	(Adjalian *et al.,* 2014)
A. sceptrum	Abomey calavi, Benin	Leaf sheaths	β-pinene (42.4%), β-pinene (5,7%)	(Adjalian *et al.,* 2014)
A. sceptrum	Abomey calavi, Benin	Rhizomes	β-pinene (15.9%), β-terpineol (l5.2%), β-caryophyllene (13.9%)	(Adjalian *et al.,* 2014)
A. sceptrum	Lagos State, Nigeria	Seeds	1,8-cineole (81.9 %), β-terpineol (10.1%), β-pinene (4.8%)	(Owolabi *et al.,* 2010)
A. strobilaceum	Ivory Coast	Leaves	β-caryophyllene (36.1%), β-selinene (15.9%), germacrene A (10.8%)	(Diomandé *et al.,* 2012)
A. stipulatum	Owando, Congo Republic	Seeds	β-pinene (428.2g/kg), β-caryophyllene (91.7g/kg), α-humulene (77.4g/kg)	(Ngakegni *et al.,* 2013)
A. stipulatum	Owando, Congo Republic	Husks	β-pinene (235.2g/kg), 1,8-cineol (143.6g/kg), α-terpineol (122.1g/kg)	(Ngakegni *et al.,* 2013)
A. stipulatum	Kinshasa, Congo Republic	Leaves	Thymol (34.0%), eugenol (7.2%), p-cymene (6.2%)	(Cimanga *et al.,* 2002)
A. sulcatum	Mbalmayo, Cameroon	Fruits	β-guaiene (26.7%), β-guaiene oxide (18.1%), limonene (10.5%)	(Menut & Lamaty, 1991)
A. sulcatum	Afan Oyo, Cameroon	Leaves	β-Caryophyllene (23.3%), β-Phellandrene (10.6%), β-Pinene (9.5%)	(Nyegue *et al.,* 2014)

Aframomum melegueta K. Schum.

Synonyms: *Aframomum grana-paradisi* (L.) K.Schum., *A. meleguetella* K.Schum., *Alexis grandiflora* (Sm.) Salisb., *Alpinia grana-paradisi* (L.) Moon, *Amomum elatum* Salisb., *A. grana-paradisi* L., *A. grandiflorum* Sm., *A. melegueta* Roscoe, *A. melegueta* var. *violacea* Ridl., *Cardamomum grana-paradisi* (L.) Kuntze, *C. grandiflorum* (Sm.) Kuntze, *Torymenes officinalis* Salisb.

A. melegueta is commonly known as "lligator pepper "or "Grain of paradise" (Lawal *et al*., 2007). It is a perennial species native to western Africa. The *A. melegueta* seeds are used as a spice as well as

treatment of diarrhea, stomachaches, and snakebites (Belayneh & Bussa, 2014). Studies reported that the seeds of this species possessed pharmacological properties such as cytoprotection, anti-ulcer and antimicrobial effects (Kamtchouing, 2002). The major constituents of A. *melegueta* were mainly composed of sesquiterpene hydrocarbons, followed by oxygenated monoterpenes, oxygenated sesquiterpenes and monoterpene hydrocarbons. The leaf and root essential oils of A. *melegueta* collected from south west Nigeria contained myrtenyl acetate as the most abundant compound, followed by isolimonene, γ-elemene, pinocarvyl acetate and cyperene. Additionally, the major constituents in stem oil had caryophyllene oxide, myrtenyl acetate and β-eudesmene as main constituents while the seed oil was made of α-caryophyllene, β-caryophyllene and linalool (Owokotomo, 2014). Meanwhile, the seed oil of A. *melegueta* grown in Bayelsa State, Nigeria was found to be rich in carvone, menthol and methone (Owokotomo, 2014). The leaf oil of this species from Lagos State, Nigeria was dominated by sabinene, α-pinene and β-caryophyllene (Lawal *et al.*, 2015).

Another sample of A. *melegueta* collected from Akure, Nigeria has been reported to possess a wide diversity of chemical composition in essential oils from different plant parts. Accordingly, myrtenyl acetate, limonene and γ-elemene were the major components in the leaf oil. The stem oil was characterized by the predominance of caryophyllene oxide, myrtenyl acetate and β-eudesmene. The seed oil was made of α-caryophyllene and β-caryophyllene while essential oil of rhizomes was found to be rich in myrtenyl acetate, pinocarvyl acetate and cyperene (Owokotomo, 2018). Meanwhile, the seed oil of this species from the same location (Akure, Nigeria) that reported from another study had eugenol, α-caryophyllene, β-caryophyllene as the major compounds (Adefegha *et al.*, 2017). In addition, the leaf and seed essential oils of A. *melegueta* from the Central African Republic contained β-pinene, β-caryophyllene, α-humulene and germacrene D as the major components (Lamaty *et al.*, 1993). The seed oil of A. *melegueta* from Ojo Lagos, Nigeria had 2-octyl acetate, linalyl acetate and α-humulene as the main compounds (Lawal *et al.*, 2017) while α-humulene, β-caryophyllene and humulene oxide II were shown by the seed oil from Ibadan, Nigeria towards the same species (Pavela *et al.*, 2016). Finally, the fruit essential oil of A. *melegueta* collected from Foumbam, Cameroon presented a characteristic composition with 1,8-cineole, α-terpineol and β-pinene as the major compounds (Kamte *et al.*, 2017) whereas the fruit oil from Mbalmayo, Cameroon was mainly composed of α-humulene, humulene oxide II and caryophyllene oxide (Menut *et al.*, 1991).

Aframomum daniellii (Hook.f.) K.Schum.

Synonyms: *Amomum afzelii* Hook. f., *Amomum angustifolium* T.Hanb., *Amomum daniellii* Hook.f., *Cardamomum daniellii* (Hook.f.) Kuntze.

A. *daniellii* is commonly referred to as "African cardamom" (Menut *et al.*, 1991). It is a large robust perennial plant and is widely found throughout central and west African countries (Adegoke *et al.*, 2000). Seeds and roots of this species has been known for their traditional medicine to use as antihelminthic, laxative and purgative (Bouquet, 1969). Rhizome extracts were effectual in the therapy of toothache and body odor. In addition, A. *daniellii* seeds were used to the flavor foodstuffs because of their olive-brown and shiny characteristics (Tane *et al.*, 2005).

The major components of A. *daniellii* essential oils were characterized by the predominance of monoterpene hydrocarbons, followed by oxygenated monoterpenes and sesquiterpenoid hydrocarbons. The essential oils obtained from various plant parts of A. *daniellii* grown in Akwa Ibom, Nigeria have been reported. Accordingly, the stem, rhizome and pod oils possessed β-pinene, α-phellandrene and γ-terpinene as the major compounds. The oil of leaves was found to be rich in β-pinene, caryophyllene oxide and β-caryophyllene while the seed oil was made of 1,8-cineole, α-terpineol, β-pinene (Essien *et al.*, 2017). Similarly, the wide diversity of chemical composition in essential oils from different plant parts of A. *daniellii* from Bafoussam, Cameroon has been presented. For instance, the seed essential oil was dominated by 1,8-cineole, α-terpineol, geraniol and β-pinene (Pavela *et al.*, 2016; Dongmo SCM *et al.*, 2019; Meffo *et al.*, 2019). The essential oil obtained from pericarps contained β-pinene, sabinene and linalool as the major components while the leaf oil was characterized by the predominance of sabinene, *(E)*-caryophyllene and β-pinene (Pavela *et al.*, 2016; Kamte *et al.*, 2017). Also, the fruit oil of A. *daniellii* from Balengou, Cameroon was mainly made of 1,8-cineole, limonene and β-pinene (Menut *et al.*, 1991). The leaf oil of A. *daniellii* from Lagos State, Nigeria was mainly composed of β-pinene, limonene and α-pinene whereas 1,8-cineole, linalool and terpinen-4-o1 were the main compounds in the seed oil (Lawal *et al.*, 2017). The major volatile components of A. *daniellii* seeds from Rivers State, Nigeria included 1,8-cineole, β-pinene and α-terpineol (Emmanuel *et al.*, 2020) while eugenol, 1,8-cineole and β-caryophyllene were the major components in the seed oil collected from Akure, Nigeria (Adefegha *et al.*, 2017). In addition, the pod oil from Ibadan, Nigeria (Olosunde *et al.*, 2015) and the fruit oil from São Tomé and Príncipe (Martins *et al.*, 2001) were found to be rich in 1,8-cineole, β-pinene and α-terpineol.

Aframomum corrorima (A.Braun) P.C.M.Jansen.

Synonyms: *Aframomum korarima* (C.Pereira) Engl., *A. usambarense* Lock, *Amomum corrorima* A.Braun, *A. corrorima* P.J.Braun, *A. korarima* C.Pereira.

A. *corrorima* is also known as "Korarima", "Ethiopian cardamom" or "false cardamom" and is native to western Ethiopia. It is an aromatic perennial herb and usually large in size (1–2 meters high). In Ethiopian cuisine, this plant was commonly used as an ingredient in berbere, mitmita, awaze. Additionally, the seeds of Korarima were used in traditional medicine as a laxative, tonic and carminative (Zakir, 2018).

The major components of A. *corrorima* essential oils were mainly composed of oxygenated monoterpenes, followed

by monoterpene hydrocarbons. The major components of the essential oil obtained from seeds of A. *corrorima* grown in southern Ethiopia included β-caryophyllene, β-pinene and caryophyllene oxide whereas the rhizome oil possessed γ-terpinene, β-pinene and β-caryophyllene as the major compounds (Eyob *et al.*, 2008). The pod essential oil of A. *corrorima* from southern Ethiopia was mainly composed of γ-terpinene β-pinene and α-phllandrene while 1,8-cineole and sabinene were the major components of the seed oils from southern Ethiopia (Eyob *et al.*, 2007) and Merkato, Ethiopia (Hymete *et al.*, 2006). The major volatile components of A. *corrorima* husks from Merkato, Ethiopia included *(E)*-nerolidol, β-caryophyllene and caryophyllene oxide (Hymete *et al.*, 2006). In addition, the seed oils of A. *corrorima* collected from Saudi Arabia and Madagascar contained 1,8-cineole as the most abundant compound (Baser & Kürkçüoglu, 2001; Noumi *et al.*, 2018). Followed by (*E*)-nerolidol, α-terpinyl acetate (Baser & Kürkçüoglu, 2001) and terpinen-4-ol, limonene (Noumi *et al.*, 2018).

Aframomum cereum (Hook.f.) K.Schum.

Synonyms: *Aframomum sceptrum* (Oliv. & D.Hanb.) K.Schum., A. *masuianum* (De Wild. & T.Durand) K.Schum., *Amomum cereum* Hook.f., A. *masuianum* De Wild. & T.Durand, A. *sceptrum* Oliv. & D.Hanb., *Cardamomum cereum* (Hook.f.) Kuntze, *C. sceptrum* (Oliv. & D.Hanb.) Kuntze, *Zerumbet autranii* Heckel.

Aframomum cereum (Hook.f.) K.Schum. is commonly known as a synonym *Aframomum sceptrum* (Oliv. & D.Hanb.) K.Schum. and also known as 'Oburo etu' or 'Ehin-edo' in Nigerian. This species extensively grows in humid forest regions of tropical Central Africa that the height reaches about 6 meters. In African traditional medicine, the extracts of A. *sceptrum* were used to treat dysentery and intestinal helminthes (*T*rypanosomiasis) (Okpekon *et al.*, 2004). Limbo and leaf sheaths of this plant were used to cure digestive candidiasis and female infertility (Okpekon *et al.*, 2004). Also, several bioactivities of A. *sceptrum* extracts, including antioxidant, antispasmodic and antimicrobial activities have been reported by previous studies (George, 2011).

A. *sceptrum* essential oils were often composed of relatively equal amounts of monoterpene hydrocarbons and oxygenated sesquiterpenes. The leaf oil isolated from A. *sceptrum* grown in Ivory Coast was found to be rich in β-pinene, 1,8-cineole and α-humulene while the rhizome essential oil was made of δ-elemene, β-pinene and α-humulene (Rana *et al.*, 2010). Meanwhile, the rhizome oil of this species from the same location (Ivory Coast) that reported from another study had β-pinene, caryophyllene oxide and cyperene as the major compounds (Cheikh-Ali *et al.*, 2011). In addition, β-pinene was the most abundant component in the essential oils from leaf sheaths and rhizomes collected from Abomey calavi, Benin, followed by α-pinene, α-terpineol and β-caryophyllene whereas the limbo oil showed β-caryophyllene, β-pinene and α-humulene as the main components (Adjalian *et al.*, 2014). Furthermore, the essential oil of seeds obtained from A. *sceptrum* from Lagos State, Nigeria was mainly attributed to the presence of 1,8-cineole, α-terpineol and β-pinene (Owolabi *et al.*, 2010).

Aframomum giganteum (Oliv. & D.Hanb.) K.Schum.

Synonyms: *Aframomum giganteum* var. *giganteum*, A. *giganteum* var. *puberulifolium* Koechlin, *Amomum giganteum* Oliv. & D.Hanb., *Cardamomum giganteum* (Oliv. & D.Hanb.) Kuntze.

A. *giganteum* is a large species that can reach a height of up to 6 meters. This plant extensively grows in tropical regions of Central Africa. All plant parts of A. *giganteum* possess an extensive and characteristic flavor. Natives in Central Africa regions used several plant parts of this species such as fruits, leaves, seeds and stems as an indigenous medicine for its healing properties (Adjanohoun, 1998). Notably, the leaf decoction, fresh juice or macerated rhizomes were used by Congolese people to treat heart pains, cough, conjunctivitis and tooth pains (Bouic, 2001) (Awad & Fink, 2018). The composition of essential oils isolated from A. *giganteum* have been reported by previous studies. Accordingly, the seed essential oil of A. *giganteum* collected from the Congo Republic was characterized by the predominance of β-pinene, 1,8-cineol and α-selinene while the husk oil possessed α-selinene, linalool and β-pinene as the major components (Ngakegni *et al.*, 2013). In addition, the leaf oil of A. *giganteum* grown in Gabon was found to be rich in *cis*-pinocamphone, *cis*-pinocamphone and *trans*-verbenol while caryophyllene oxide, β-caryophyllene and β-caryophylla-4(14),8(15)-dien-5-ol were the main compounds in the rhizome oil (Agnaniet *et al.*, 2004). The major volatile components of the A. *giganteum* stems from the Africa Republic contained linalool, linalyl acetate and α-terpineol (De Bernardi *et al.*, 1981).

Aframomum citratum (C.Pereira) K.Schum.

Synonyms: *Amomum citratum* C.Pereira, *Amomum macrolepis* K.Schum., *Cardamomum citratum* (C.Pereira) Kuntz.

A. *citratum* is a herbaceous and perennial rhizomatous species throwing up stems to 3 meters tall (Burkil, 2000). This species extensively grows spontaneously in humid forest regions of tropical Africa, especially in Cameroon (Koechlin, 1665). Shoots and seeds of A. *citratum* were used as a green vegetable or a spice in Cameroon. Also, seeds were the major ingredient in "Mbongotjobi", a common condiment in Cameroon. In traditional medicine, seed extracts were used to treat stomach ache, lombalgies (Abondo, 1993), malaria, bacterial infections, cancers and as an aphrodisiac (Titanji *et al.*, 2008) (Kuete e*t al.*, 2011).

The chemical composition of the essential oils isolated from A. *citratum* was characterized by the predominance of oxygenated monoterpenes. Geraniol was the most abundant compound in the essential oils of A. *citratum* seeds collected from Bafoussam and Yaounde Cameroon while the insignificant portion of the total included linalool, geranyl acetate and myrcene (Amvam *et al.*, 2002; Meffo *et al.*, 2019; Dongmo *et al.*, 2019).

In addition, the essential oil of A. *citratum* leaves grown in Yaounde Cameroon was dominated by β-pinene, α-pinene and β-caryophyllene (Amvam *et al.*, 2002). Finally, the essential oil of A. *citratum* seeds from Kribi, Cameroon was found to be rich in geraniol, linalool and myrcene (Chalchat *et al.*, 1997).

Aframomum pruinosum Gagnep.

A. *pruinosum* is a large shrub (about 5 meters tall) growing naturally beneath the forest canopy of the western region of Cameroon, including Dschang, Fontem, Bafoussam and the central region of Mbalmayo. This species is also located in Gabon and Central Africa (Koechlin, 1965). Seeds of this species have a pleasant scent and slightly sweet flavor. In traditional medicine of Cameroon, these plants are used to cure sterility in women (Abondo, 1993).

The chemical composition of essential oils obtained from different plant parts of A. *pruinosum* mainly belonged to monoterpene hydrocarbons, followed by oxygenated monoterpenes and oxygenated sesquiterpenes. The specimens of this species collected from Fontem, Cameroon showed the wide diversity of chemical profiles in essential oils. For instance, the seed oil possessed (*E*)-nerolidol, β-ocimene, α-bisabolol as the major compounds. The pericarp oil contained a main proportion of β-pinene, 1,8-cineole and caryophyllene oxide. β-caryophyllene, β-pinene and caryophyllene oxide were found as the major components in the leaf essential oil while the rhizome oil was characterized by the predominance of β-pinene, linalool and cyperene (Nguikwie *et al.*, 2013). Furthermore, the leaf essential oils of A. *pruinosum* collected from Yaounde and Dshang, Cameroon possessed β-pinene, β-caryophyllene and caryophyllene oxide as the main compounds whereas the seed oil was rich in (E)-nerolido, β-ocimene and linalool (Menut *et al.*, 1994; Amvam *et al.*, 2002).

Aframomum letestuanum Gagnep.

A. *letestuanum* is an herbaceous plant that has a height reaching 3 meters. This species is commonly cultivated in the western Cameroon for the harvesting of fruits. In traditional medicine, A. *letestuanum* was used to treat muscular pains, nausea, vomiting, hemorrhage (Nguenang *et al.*, 2018) and and female infertility (Telefo *et al.*, 2011). Recent studies reported that leaf extracts of A. *letestuanum* possessed the antimicrobial activities as well as contained several biological compounds, including alkaloids, flavonoids, polyphenols, saponins, steroids, tannins and triterpenes (Nguenang *et al.*, 2018). The chemical profiles of essential oils obtained from A. *letestuanum* were mainly characterized by the presence of monoterpene hydrocarbons and oxygenated sesquiterpenes, followed by oxygenated monoterpenes. The seed essential oils of A. *letestuanum* collected from Yaounde and Bamendjida, Cameroon possessed (*E*)-nerolidol and linalool as the main compounds (Amvam *et al.*, 2002; Nguikwie *et al.*, 2013). The main components of the pericarp essential oil from Bamendjida, Cameroon were identified to be β-pinene, linalool and caryophyllene oxide. Also, the principal compounds of the leaf oil from Bamendjida region were caryophyllene oxide, β-caryophyllene and β-pinene while the main components in the rhizome oil were found to be β-pinene, cyperene and α-pinene (Nguikwie *et al.*, 2013).

Aframomum alboviolaceum (Ridl.) K.Schum.

Synonyms: *Aframomum biauriculatum* K.Schum., A. *candidum* Gagnep., A. *latifolium* K.Schum., A. *macrospermum* (Sm.) Burkill, A. *stipulatum* (Gagnep.) K.Schum., *Amomum alboviolaceum* Ridl., A. *bitacoum* Gagnep., A. *latifolium* Afzel., A. *macrospermum* Sm., A. *stipulatum* Gagnep., *Cardamomum latifolium* Kuntze, *Ceratanthera beaumetzii* Heckel.

A. *alboviolaceum* is an herbaceous species reaching up 3 meters tall that is extensively distributed in Africa (Inkoto *et al.*, 2021). The rhizomes of this plant are used as a food in Ivory Coast. In African traditional medicine, A. *alboviolaceum* has been used to cure many diseases. For example, all plant parts were used to treat diuretic, anti-helminthic, anti-parasitic, anti-malaria and fever in Cameroon (Titanji *et al.*, 2008). In the Democratic Republic of the Congo, A. *alboviolaceum* leaves were used to cure headache, gastritis, cough, fever, amoebic dysentery and haemorrhoids (Inkoto *et al.*, 2021), malaria, headaches, myoma, hypertension, gastritis and pruritis, pruritus and filarial (Ngbolua *et al.*, 2016). In addition, A. *alboviolaceum* extracts also had the bioactivities such as antimicrobial, antioxidant, anti-sickling, antimalarial, anticancer effects (Kwazou *et al.*, 2009; Bongo, 2017). Several bioactive compounds, including phenolic acids, anthocyanins, flavonoids, iridoids, tannins, alkaloids, coumarins, anthraquinones and tri-terpenes have been identified in the extracts of A. *alboviolaceum* (Kwazou *et al.*, 2009; Bongo, 2017). The chemical components of the essential oils isolated from A. *alboviolaceum* were characterized by the predominance of mono-oxygenated sesquiterpenes and diterpenes, followed by di-oxygenated sesquiterpenes and sesquiterpenes hydrocarbons. The rhizome oil of A. *alboviolaceum* (Ridl.) K.Schum. colleted from Contuboel, Guinea-Bissau was found to be rich in intermedeol, carotol and spathulenol (Abreu & Noronha, 1997). Also, A. *biauriculatum* K.Schum., a synonym of A. *alboviolaceum* (Ridl.) K.Schum., collected from Zambia has been investigated the composition of essential oils. Accordingly, the leaf oil of this species possessed β-pinene, β-caryophyllene, α-pinene as the major compounds while the main components in the rhizome oil were β-pinene, 1,8-cineole and α-terpineol (Chisowa *et al.*, 1998).

Other *Aframomum* Species

Other *Aframomum* species had a lesser report by reason of their limit of distribution and commercial interest. For instance, the essential oils obtained from pericarps and rhizomes of A. *dalzielii* Hutch. collected from Fontem, Cameroon were comprised mainly of β-pinene, sabinene and α-pinene. The major constituents of the leaf oil from the same location were β-caryophyllene, β-pinene and caryophyllene oxide while (*E*)-nerolidol and 2-heptyl acetate were the compounds occurring in higher amounts in the seed oil (Nguikwie *et al.*, 2013). In addition, the leaf essential oil of A. *hanburyi* K.Schum. collected from Yaounde, Cameroon was mainly characterized by the

presences of β-pinene, α-pinene and limonene whereas *(E,E)*-farnesol, linalool and terpinolene were the major constituents in the seed oils towards the same species (Amvam *et al.*, 2002). Also, the main components of the fruit essential oil of A. *sulcatum* (Oliv. & D.Hanb. ex Baker) K.Schum. from Mbalmayo, Cameroon were identified to be α-guaiene, δ-guaiene oxide and limonene (Lamaty *et al.*, 1993) while the leaf oil of this species from Afan Oyo, Cameroon contained β-caryophyllene, β-phellandrene, α-pinene as the major compounds (Nyegue *et al.*, 2014).

The quantitatively significant components of the leaf oil of A. *elliotti* (Baker) K.Schum. grown in Ivory Coast were β-pinene, β-caryophyllene and α-pinene while the rhizome oil possessed linalool, 1,8-cineole, β-pinene as the major constituents (Diomandé *et al.*, 2012). The leaf essential oil obtained from A. *geocarpum* Lock & J.B.Hall, another species collected from Ivory Coast, contained β-caryophyllene, α-humulene and β-pinene as the main components while the rhizome oil was found to be rich in β-pinene, cyperene and caryophyllene oxide (Diomandé *et al.*, 2012). Furthermore, the rhizome and leaf essential oils of A. *longiscapum* (Hook.f.) K.Schum. collected from Ivory Coast possessed β-pinene as the most abundant compound, followed by β-caryophyllene, linalool and α-pinene (Diomandé *et al.*, 2012). The leaf oil of A. *strobilaceum* (Sm.) Hepper from Ivory Coast possessed β-caryophyllene, β-selinene and germacrene A as the main constituents (Diomandé *et al.*, 2012). Moreover, the main components of the leaf essential oil of A. *latifolium* K.Schum. from Ivory Coast were identified to be β-pinene and β-caryophyllene, sabinene (Tia *et al.*, 2011) while this leaf oil of this species from Oyo State, Nigeria was mainly characterized by the presences of 1,8-cineole, β-pinene and cyclofenchene (Olagoke & Amusat, 2019; Adjalian *et al.*, 2014; Adjalian *et al.*, 2014).

The essential oils of several plant parts of A. *stipulatum* (Gagnep.) K.Schum. from the Congo Republic have been reported. For instance, the principal compounds of the leaf oil from Kinshasa region were thymol, eugenol and p-Cymene. The husk oil of this species possessed β-pinene, 1,8-cineol and α-terpineol as the major components while β-pinene, β-caryophyllene and α-humulene were the dominant compounds of the seed oil (Ngakegni *et al.*, 2013). In addition, the essential oils of A. *exscapum* (Sims) Hepper collected from various locations of the Ivory Coast have been reported. As a consequence, the leaf oils from Malamalasso, Nianda North, Nianda South and Nianda East of Ivory Coast contained 1,8-cineole, α-pinene and germacrene D as the major compounds whereas the 1,8-cineole, (E)-nerolidol, α-terpineol were the main components of this sample from Assouba, Ivory Coast (Muriel *et al.*, 2011). Moreover, the major constituents of essential oil A. *sanguineum* seeds grown in Bujumbura, Burundi were found to be 1,8-cineole, α-terpinyl acetate and geranyl acetate (Hari *et al.*, 1994). The seed essential oil of A. *angustifolium* (Sonn.) K.Schum. from Madagascar contained a main proportion of β-pinene, β-caryophyllene and cis-pinocarvyl acetate (Baser & Kürkçüoglu, 2001).

CONCLUSIONS

The present review provides an overview of all the published studies on the chemical constituents of the essential oils isolated from *Aframomum* species. The various *Aframomum* plants collected from different regions had a diversity of chemical constituents. The essential oils of *Aframomum* are richer in chemical components of commercial interest in pharmaceutical industries. The result of the present review will contribute to the beneficial potentials and give the evidence for future applications of *Aframomum* species in the medicinal and pharmaceutical industries.

AUTHOR'S CONTRIBUTIONS

This study was designed Hong Thien Van. All authors searched and handled the data. Hong Thien Van prepared the manuscript and resolved all the queries of reviewers.

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