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Costus afer Ker Gawl (Costaceae): A Review on Its Medicinal uses with Focus on Potential Anti-Inflammatory Effect

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Authors' contributions

This work was carried out in collaboration between all authors. Authors JND, AZI and FBM designed the study, wrote the methodology and wrote the first draft of the manuscript. Authors AZI, DMK, PLM, ISW, VML, RIK, PSN, RMB, JZN, BML, GKM, GLT, MMN, PKM, JND and FBM managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

More than 80% of the population in Africa by the World Health Organization (WHO) leans on endogenous knowledge to solve their primary health care problems. In this study, we examined the relevance of *Costus afer* Ker Gawl, a plant called ginger lily, spiral ginger or bush cane. It is believed to be used in traditional medicine practice (TMP) to treat and manage many conditions including diabetes mellitus, stomach ailments, arthritis, inflammation. These alleged traditional incited large researchers to conduct studies on the plant to amass scientific evidence. However, these results are sparse, and thus, an inventory through the present search using online search engines such as Google Scholar, PubMed, Science Direct, Web of Science, Scopus and Chemical Abstracts for the period from 1990 to 2021; provides a bibliographic actualization on the plant, taking into account its traditional uses, phytochemical and nutritional constituents, pharmacological activities and toxicological effects. The online search included the use of the keywords, "*Costus afer* Ker-Gawl" or "*Costus afer*". It should be noted that the stem and leaves of the plant contain consistent amounts of micronutrients and macronutrients. The leaves, stem, rhizomes of *C. afer* contain several steroidal sapogenins, aferosides, dioscin and paryphyllin C and a flavonoid glycoside, kaempferol-3-O-α-L-rhamnopyranoside. Experimental studies on various parts of the plant have shown biological activities such as anti-hyperglycemic, hepatocellular protection, cardioprotection, nephroprotection, CNS depressant, analgesic, antiarthritis, antibacterial and antioxidant. This wide range of biological properties of *Costus afer* Ker Gawl would be largely attributed to the essential oil compounds such as Sabinene, β-pinene and β-caryophyllene which are among the major compounds of this plant. Based on these obvious data, it is concluded that the plant could be used as an alternative and complementary therapy for many diseases related to oxidative stress so will guide us future research on the use of *Costus afer* Ker Gawl as an anti-inflammatory.

Keywords: Anti-inflammatory; diosgenin; costus afer Ker gawl; anti-spasmodic activity; phytomedicine.

1. INTRODUCTION

1.1 Background

Considered a primary physiological defense mechanism, inflammation helps the body protect itself against infection, burns, toxic chemicals, allergens, or other harmful stimuli. When uncontrolled and persistent, inflammation can act as an etiological factor for many of these chronic diseases [1]. Although it is a defense mechanism, the complex events and mediators involved in the inflammatory response can infer, maintain or worsen several diseases [2]. Presently consumed anti-inflammatories are associated with serious side effects. Thus, the development of potent anti-inflammatory drugs with fewer side effects is needed.

The pathophysiological pathways essential for drug targeting are currently: the metabolism of arachidonic acid; the complement cascade; phagocytosis and other cellular functions; autoimmune processes; protein kinase C and other enzymes involved in second messenger systems [3]. It is recently known that early inflammatory changes in damaged tissues incite the release of various biologically active materials from polymorphic nuclear leukocytes, lysosomal enzymes and the like. The vascular effects are mainly mediated by prostaglandins, kinins and vasoactive amines (e.g. histamine, released by mast cells), which lead to increased vascular permeability thus leading to plasma exudation.

The inflammatory process involves a complex interplay between red blood cells, the blood vessels themselves and the cells of the tissue involved. This process can be seen as a coordinated response of a large number of cells to an initial stimulus [4].

The immigrant cells exert little effect by their mere presence, but initiate the entire complex inflammatory response due to the materials they secrete or release into the extracellular environment. These materials include molecules that exacerbate the response by attracting more inflammatory cells, inhibitors that serve to reduce the severity of reactions, histotoxic agents such as proteases, oxygen metabolites and cations, and signals to inflammatory and surrounding

tissues to implement all or part of the complex reactions of which they are capable [4].

It is not desirable for uncontrolled inflammation to continue. Reversible features such as pain, redness, warmth and swelling are joined by a less transient fifth feature, namely loss of function of the affected organs. ultimately, control of inflammation is sought to protect bodily function [5,6].

Various experimental models are used to assess inflammation in the field of inflammation research. The usual methods for determining whether compounds have anti-inflammatory activity is to test them against animal and biochemical models of inflammation. There is no experimental model of inflammation covering all aspects of inflammation [7].

We can divide experimental models for assessing inflammation into two broad classes, what are: (1) acute inflammation and (2) chronic inflammation. Acute models test drugs that regulate blood flow (erythema), changes in vascular permeability, leukocyte migration and chemotaxis, phagocytosis - PMNL and other phagocytic cells, measurement of local pain, antipyretic activity, local analgesic action and rat paw edema. Chronic models find drugs that can modulate the disease process, including sponge and pellet implants and granuloma pockets that deposit granulation tissue, adjuvant-induced arthritis, and rabbit monoarticular arthritis that has an immune etiology [7]. The usual starting point for anti-inflammatory testing is experimental inflammation in the whole animal. Different variations of his widely used experiments, in particular the rat paw edema test. It can be adapted in several ways by using different inflammatory agents to try to mimic pathological inflammation and arthritis [3].

The search for alternative sources of anti-inflammatories is of primary interest to research institutes, pharmaceutical companies, etc. [8]. These are the adverse side effects experienced by patients with rheumatoid arthritis after using synthetic steroidal or non-steroidal anti-inflammatory drugs (NSAIDs). In addition, the World Health Organization has reported that NSAIDs are often associated with drug-induced toxic effects or adverse side effects during long-term use [9,10]. Additionally, alternative sources of plant-derived anti-inflammatory drugs are readily accessible, available, and affordable and contain bioactive compounds of therapeutic value.

Costus afer (*C. afer*) Ker Gawl often known as ginger or bush cane, it belongs to the *Zingiberaceae* family, currently known as *Costaceae*. It is one of the 150 species of all, perennial and rhizomatous grasses that make up this family [11]. *C. afer* is commonly found in moist or shady forests and river banks in tropical West Africa. *C. afer* is often used as a medicinal herb throughout tropical Africa, especially for inflammation, coughs, hemorrhoids, miscarriages, arthritis, liver disorders, helminths, epileptic seizures and rheumatism. Additionally, used as a laxative, diuretic, and serves as an antidote to poison [12-14].

The rhizomes of *C. afer* contain several steroidal sapogenins, dioscin, aferosides and paryphyllin C and the flavonoid glycoside kaempferol 3-O-α-L-rhamnopyranoside [11]. The most abundant group of volatile compounds in the essential oil of the leaf are sesquiterpenoids [11]. Chloroform and methanol extracts of the aerial parts reduced carrageenan-induced rat paw edema [6], while stem and leaf extracts of *C. afer* exhibited antioxidant and hepatoprotective activities [17, 18].

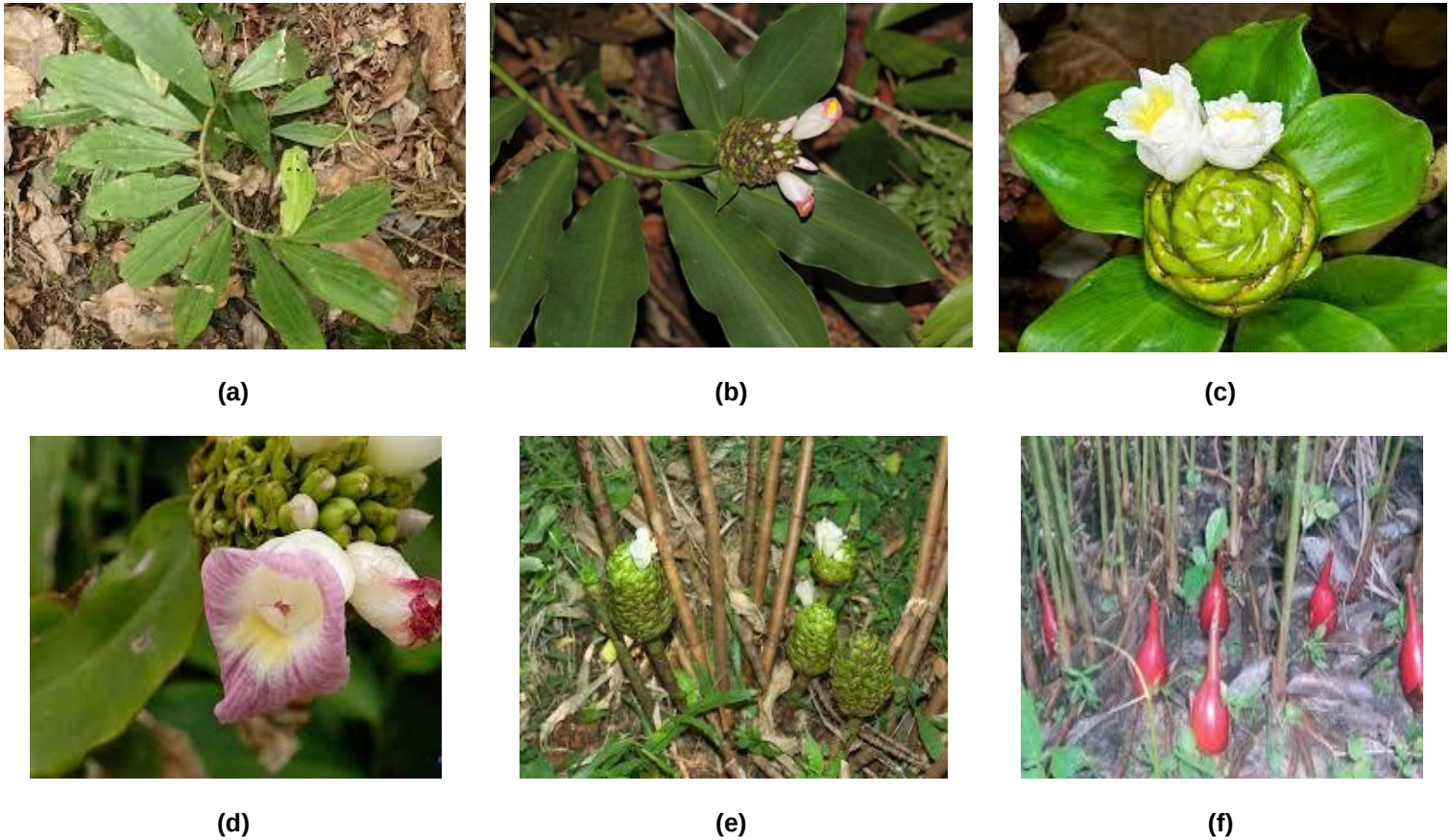
The present literature review was undertaken in order to provide a comprehensive summary and reviews of recently published literature concerning the ethnopharmacological use, phytochemistry, biological and pharmacological activities as well as toxicological research of *Costus afer* and its components with a view to its integration into a future research program on the screening of tropical plants (TPSR) for its anti-inflammatory properties mainly on humans. This review aims to also provide information as a basis for the further development and use of this herbal resource.

1.2 Classification

Scientific Name: *Costus afer* (*C. afer*) Ker Gawl
Kingdom: *Plantae* – Plants
Subkingdom: *Tracheobionta* -Vascular plants
Superdivision: *Spermatophyta*
Class: *Equisetopsida*
Order: *Zingiberales*
Family: *Costaceae*
Gender: *Costus*

Species: *Costus afer* Ker Gawl., 1823

[http://www.theplantlist.org/tpl1.1/search?q=Costus+afer19-20]



(a) **(b)** **(c)**

(d) **(e)** **(f)**

Fig. 1. Whole plant (a), Leaves, fruit and flowers (b), Fruit and leaves (c), Flowers (d), stem (e) and rhizomes of *Costus afer*

1.3 Taxonomy, Ethnic Names, and Ethnopharmacological Importance

Costus afer Ker-Gawl is from the domain *Eukarya*, thus belonging to the kingdom *Plantae*, and to the family *Zingiberaceae*, currently known as *Costaceae* [21]. *C. afer* belongs to the genus *Costus* and the species *afer* [22].

1.4 Botanic Description

C. afer is a tropical, herbaceous, rhizomatous, monocotyledonous and relatively tall, unbranched plant belonging to the family *Costaceae*. It is widely distributed in moist or shady forests in tropical and West Africa [23].

Perennial herbaceous plant with rhizome, *C. afer* is a plant that can reach a height of 4 m. Arranged in a spiral, the leaves are simple and entire. The sheath is tubular, closed, green with violet spots; ligule 4-8 mm long, leathery and glabrous; the petiole is 4-12 mm long; blade elliptical to obovate, 15-35 cm x 3.5-9.5 cm, base rounded to subcordate, acuminate apex, margin slightly hairy, usually glabrous above, sometimes shortly hairy below. The inflorescence is a very compact, terminal, conical spike 2.5-7.5 cm long, sessile; bracts oblong, convex, 3.5 cm long, densely imbricated, upper bracts often smaller, apex truncate to rounded, green with purple markings, each subtending 2 flowers; the bracteoles are boat-shaped, 2.5 cm x 1 cm, the keel is thick and ridged, pale green with pink markings and a thin papery pink margin. The flowers are zygomorphic and bisexual. Corolla tube ± 2 cm long, hairy inside, enclosed in a bract. Fruit: ellipsoid capsule about 1 cm long, loculicidal, with many seeds and black seeds, with aril [23-24].

1.5 Origin and Geographic Distribution

In Africa, *C. afer* is distributed in the forest belt from Senegal to Ethiopia and east to Tanzania, Malawi and Angola, in southern and western Africa. It is common in Nigeria, Ghana, Togo and Cameroon. It is often planted in the home garden for medicinal purposes. *C. afer* is pantropical and comprises about 70 species, of which about 40 species are found in tropical America, about 25 in tropical Africa, and about 5 in Southeast Asia [19-23].

1.6 Ecology

Costus afer occurs in humid areas of forests and forest edges, up to 1400 m altitude. In southern Nigeria *Costus afer* is a weed of rice fields. In cultivation, it requires a rich, moist and well-drained soil (you need two parts of sphagnum for one part of silt and one part of extra-siliceous sand). It does well in shady to direct sunlight [19-23].

1.7 Propagation and Planting

Propagation of *Costus afer* can be done by seed as well as by stem or rhizome cuttings. These stems and rhizomes are cut into 2.5 cm long sections and planted in a mixture of sand and sphagnum. Successful in vitro multi-shoot cultures of *Costus afer* were retained; after one year of liquid paraffin storage, high survival rates (70–100%) were observed, and even after two years, 75% of *Costus afer* cultures remained viable [19-23].

2. METHODOLY

In this study, the research was carried on the relevant literature on *Costus afer* Ker Gawl, a plant species traditionally used as a herbal medecine. A literature search was conducted to obtain information about the phytochemistry and pharmacognosy of *Costus afer* Ker Gawl. from various electronic databases (Scifinders, Pubmed NCBI, Qwant, Scopus, Wiley, PubMed Central, Web science, Science Direct and Google scholar). The scientific name of this plant species was used as the keyword for the search [http://www.ville-ge.ch/musinfo/bd/cjb/africa/index.php?langue=an/; Plants of the World Online | Kew Science; Royal Botanic Gardens, Kew: Medicinal Plant Names Services; PROTA, Introduction — PlantUse Français (plantnet-project.org); http://www.theplantlist.org/ et CJB - Search Africa (ville-ge.ch)], along with the terms Phytochemistry and pharmacognosy. The chemical structures of the *Costus afer* naturally occurring compounds were drawn using PubChem and ChemBioDraw Ultra 15.0 software package. Finally, the bibliographic references were processed using the bibliographic software "Mendeley".

3. RESULTS AND DISCUSSION

3.1 Traditional Use and Ethnopharmacology

Taking into account endogenous knowledge, the plant has various uses, which are listed in Table 1. The pharmacological importance which is

attached to the use of the plant has led to numerous scientific research publications.

3.2 Phytochemistry Composition

It has been found that the leaves, barks and rhizomes of *Costus afer* can be considered a good source of minerals, lipids, carbohydrates, proteins, fibers and moisture, which is beneficial for human health [37-39]. Tables 2-4 show the proximal composition of leaves, bark and rhizome of *Costus afer*.

Several phytochemicals such as saponins, tannins, alkaloids, steroids, cardioglycosides, flavonoids and terpenoids have been identified in *Costus afer* stem extract [39-40].

Table 1. Ethnomedicinal uses of *Costus afer*

Country	Vernacular names	Part uses	Local uses	Ref.
Nigeria	Irekeomede, Tete-egun (Yoruba), Ogbodou (Ijaw), Opete or okpete, Ejula (Igbo), Kakizawa, Dodon kodi (Hausa)	Stem	Inflammation, Arthritis	[24,25,16,26]
		Leaves	Measles	[25]
		Rhizome	Malaria	[27]
Ghana	Osommbaa (Fante), Sommɛ (Asante), Asumbae (Ewe)	Rhizome	CNS depression, Laxative	[25,28,29,30]
		Stem	Chicken pox, Influenza	[31]
		Leaves	Oligospermia	[15]
Cameroon	Mwandando (Douala), Mandanwany (Bakweri), Nmian (Bulu)	Leaves and stem	Fodder	[25]
		Rhizome	Purgative	[25]
Senegal	Bumay (Fogny), Sungho (Dan), Zazaboto (Guere), Doï (Kru-bete)	Stem	Diuretic	[29,25,26]
		Stem, leaves and rhizome	Diabetes mellitus	[26]
		Leaves	Wound healing	[27]
Ivory Coast	Dodre (Guere do), Zazaboto (Guere),	Rhizome	Gastric ulcer	[29,20]
		Stem	Aperient	[33]
		Leaves	Jaundice	[27]
Sierra Leone	Tofa (Kono), Dan (Loko), Sungho (Dan)	Leaves	Fever	[29,27]
		Rhizome	Leprosy	[25]
		Leafy stem	Ear infection	[36]
Togo	Ukhueruohâ (Edo)	Leaves	Colic, Miscarriage	[34,29,27]
		Rhizome	Toothache	[25]
		Stem	Gonorrhea, Genital herpes	[15, 32]
Guinea-Bissau	Gogodje-suto (Fula-pulaar)	Leaves	Hypertension, Helminthic, Hepatic disorder	[25,34,14,27]
		Stem	Hemorrhoids	[25]
		Leaves, stem and rhizome	Aphrodisiac	[35]
DR Congo	Minkuisa (Kikongo)	Leaves and stem	Arthritis	[15, 25,29,27]
		Stem, aerial parts	Cough, sore throat	[15,26]
		Leafy stem	Conjunctivitis	[32]
		Leaves	Stomach ache, Hepatic disorder	[27]

Table 2. Proximate compositions of different part of *Costus afer* [37-39]

Parameter	Values (%)		
	Leaf	Stem	Rhizome
Moisture	18.63 ± 2.11	6.76 ± 0.67	71.1 ± 0.011
Total Ash	11.47 ± 1.47	10.91 ± 0.50	13.0 ± 0.06
Crude Protein	2.75 ± 0.56	2.93 ± 1.16	12.5 ± 021
Crude Fat	1.83 ± 0.43	1.75 ± 0.48	2.1 ± 0.005
Crude Fiber	21.16 ± 0.86	27.28 ± 1.54	45.2 ± 0.004
Total Carbohydrate	55.83 ± 3.71	50.38 ± 1.27	16.4 ± 0.003

Table 3. Mineral composition of the leaf, stem and rhizome of *Costus afer* [37-39]

Parameter (mg/100g)	Values (%)		
	Leaf	Stem	Rhizome
Calcium	418 ± 0.000	500 ± 0.004	350 ± 0.002
Iron	1.35 ± 0.001	1.37 ± 0.001	2.5 ± 0.006
Sodium	11.5 ± 0.050	21.5 ± 0.003	12.2 ± 0.001
Phosphorus	55.5 ± 0.020	66 ± 0.005	18 ± 0.010
Potassium	201 ± 0.002	211 ± 0.001	113 ± 0.003
Magnesium	40.1 ± 0.012	36.4 ± 0.015	28.2 ± 0.012

Table 4. Anti-nutrient composition of the leaf, stem and rhizome of *Costus afer* [37-39]

Parameter (mg/100g)	Values (%)		
	Leaf	Stem	Rhizome
Tannin	0.05±0.001	0.16 ± 0.001	0.01 ± 0.002
Saponin	1.65±0.001	1.80 ± 0.001	0.85 ± 0.006
Oxalate	3.5±0.050	3.0 ± 0.003	2.5 ± 0.001
Cyanogenic glycosides	35.7±0.020	18.90 ± 0.005	13.6 ± 0.010

Table 5. Fatty acid composition of *Costus afer* stem

Compounds	*Costus afer*	
	Retention time (min)	Composition (%)
Caprylic acid (C8:0)	8.908	0.00
Capric acid (C10:0)	10.363	0.00
Lauric acid (C12:0)	12.100	0.00
Myristic acid (C14.0)	13.743	0.02
Palmitic acid (C16:0)	15.160	25.48
Palmitoleic acid (C16:1)	16.248	2.06
Margaric acid (C17:0)	17.230	0.00
Stearic acid (C18:0)	18.057	6.37
Oleic acid (C18:1)	18.844	7.11
Linoleic acid (C18:2)	19.523	25.90
Linolenic acid (C18:3)	21.824	32.27
Arachidonic acid (C20:0)	22.359	0.52
Arachidonic acid (C20:4)	23.234	0.00
Behenic acid	23.970	0.20
Erucic acid	24.793	0.00
Lignoceric acid	25.619	0.07
Total fatty acids		100.00

Diosgenin is a very important raw material found in *C. afer* used as a precursor in the synthesis of a number of steroid drugs including corticosteroids, sex hormones, oral contraceptive

and anabolic agents. The rhizome also contains the saponins aferosides A-C, as well as diosein, parphyllin c and flavonoid glycoside kaempferol-3-O-α-L-rhamnopyranoside [41].

Table 6. Alkaloid composition of *Costus afer* stem

Compounds	*Costus afer*	
	Retention time (min)	Composition (mg/100 g)
Morphine	12.412	12.65
Methyl morphine	13.794	16.41
Papaverine	15.111	31.56
Biflorin	15.722	0.01
Narcotine	16.368	9.96
Daphnoline	16.664	0.00
Aromoline	18.042	0.00
Homoaromoline	18.988	0.00
Ambelline	19.665	0.00
6-Hydroxybuphanidine	20.599	0.00
Monocrotalline	21.251	0.00
6-Hydroxypowelline	21.794	0.00
Nitidine	22.559	0.00
Total alkaloids		70.59

Table 7. Saponin composition of *Costus afer* stem

Compounds	*Costus afer*	
	Retention time (min)	Composition (mg/100 g)
Gitogenin	17.545	0.08
Solagenin	18.588	0.01
Diosgenin	19.516	0.75
Tigogenin	20.115	0.28
Neohecogenin	20.979	0.00
Hecogenin	21.819	0.00
Sapogenin	22.600	1.12
Euphol	24.185	0.00
Saponine	25.480	0.63
Total saponins		2.87

Table 8. Flavonoid composition of *Costus afer* stem

Compounds	*Costus afer*	
	Retention time (min)	Composition (mg/100 g)
Catechin	13.549	0.00
Resveratrol	14.904	0.00
Apigenin	16.036	0.92
Daidzein	16.246	0.06
Butein	16.458	0.00
Naringenin	16.671	0.00
Biochanin	17.357	0.00
Luteolin	17.769	0.07
Kaempferol	18.050	2.77
Epicatechin	19.395	0.00
Salvagenin	20.467	0.00
Epicatechin-3-gallate	21.501	0.00
Gallocatechin	22.065	0.00
Quercetin	22.597	4.21
Isorhamnetin	23.471	0.00
Myricetin	23.965	19.75
Sinensetin	24.997	0.00

Compounds	*Costus afer*	
	Retention time (min)	Composition (mg/100 g)
Kaempferol-3-arabinoside	25.360	0.00
Naringenin	26.041	0.00
Quercitrin	27.294	0.04
Isoquercetin	27.480	0.07
Orientin	27.910	0.00
Rutin	28.195	0.39
Isoorientin	28.529	0.02
Total flavonoids		28.29

Table 9. Leaf essential oil composition of *Costus afer* Ker–Grawl [16]

Peak No.[a]	Compound	KI	Composition (%)	Method of identification[b]
	α-Thujene	927	0.8	RI, MS
	α-Pinene	938	0.6	RI, MS
	Sabinene	958	1.0	RI, MS
	β-Pinene	977	0.9	RI, MS
	∆-*3*-Carene	1050	1.9	RI, MS
	α-Terpinene	1050	1.9	RI, MS
	Terpinen-4-ol	1172	1.2	RI, MS
	trans-Piperitol	1289	2.3	RI, MS
	Geranial	129	0.4	RI, MS
	Z-Theaspirane	1297	0.5	RI, MS
	E-Theaspirane	1375	4.7	RI, MS
	β-Caryophyllene	1401	12.3	RI, MS
	Ui[c]	1401	12.3	RI, MS
	β-Ionone	1434	4.5	RI, MS
	β-Selinene	1478	1.5	RI, MS
	Z-Dihydro-farnesal	1499	1.1	RI, MS
	Z,E-Nerolidol	1527	1.6	RI, MS
	Z-Dihydro-farnesol	1575	0.6	RI, MS
	Caryophyllene oxide	1582	0.5	RI, MS
	Z,E-Farnesol	1611	9.9	RI, MS
	Z,Z-Farnesol	1631	0.4	RI, MS
	Ui[c]	1648	0.7	RI, MS
	Ui[c]	1681	0.4	RI, MS
	Ui[c]	1684	0.3	RI, MS
	Z-Dehydro-apo-farnesol	1687	0.6	RI, MS
	Ui[c]	1690	0.9	RI, MS
	Ui[c]	1712	0.9	RI, MS
	Ui[c]	1727	12.9	RI, MS
	Z-Citronellyl tiglate	1731	2.6	RI, MS
	E-Citronellyl tiglate	1749	0.7	RI, MS
	Methyl linoleate	1798	0.8	RI, MS
	β-Acoradienol	1802	1.4	RI, MS
	Sesquilavanduylyl acetate	1809	17.0	RI, MS
	Ui[c]	1886	1.0	RI, MS
	Ui[c]	2018	1.7	RI, MS
	Abietatriene	2153	4.0	RI, MS
	Ui[c]	2268	1.3	RI, MS
	Ui[c]	2376	0.3	RI, MS

[a]GC Peak number (elution order on Cpsil 5 capillary column) (BP 1); [c]Identification by KI and using the mass spectral data in the literature; [d]Unidentified compound

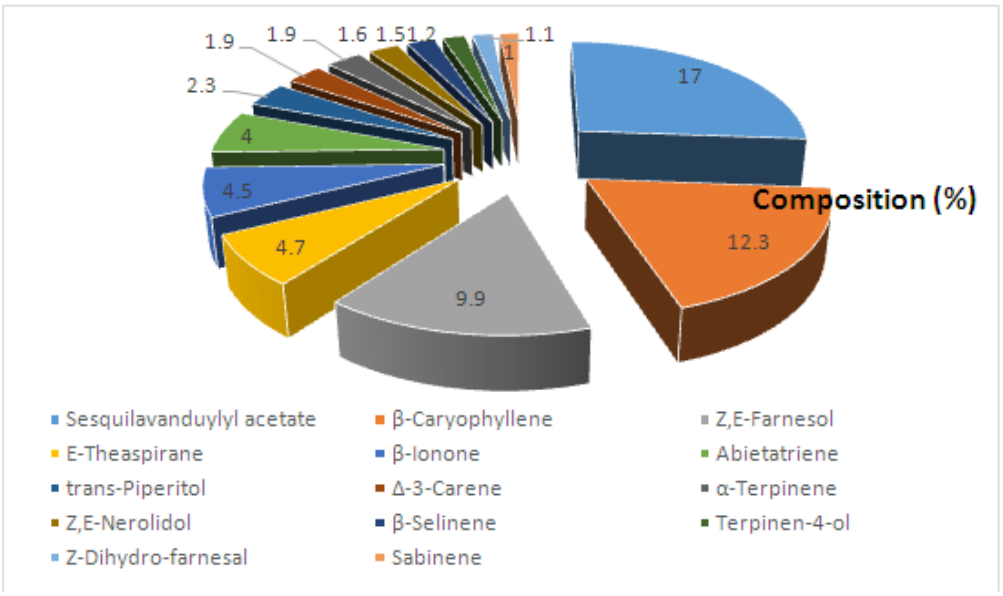
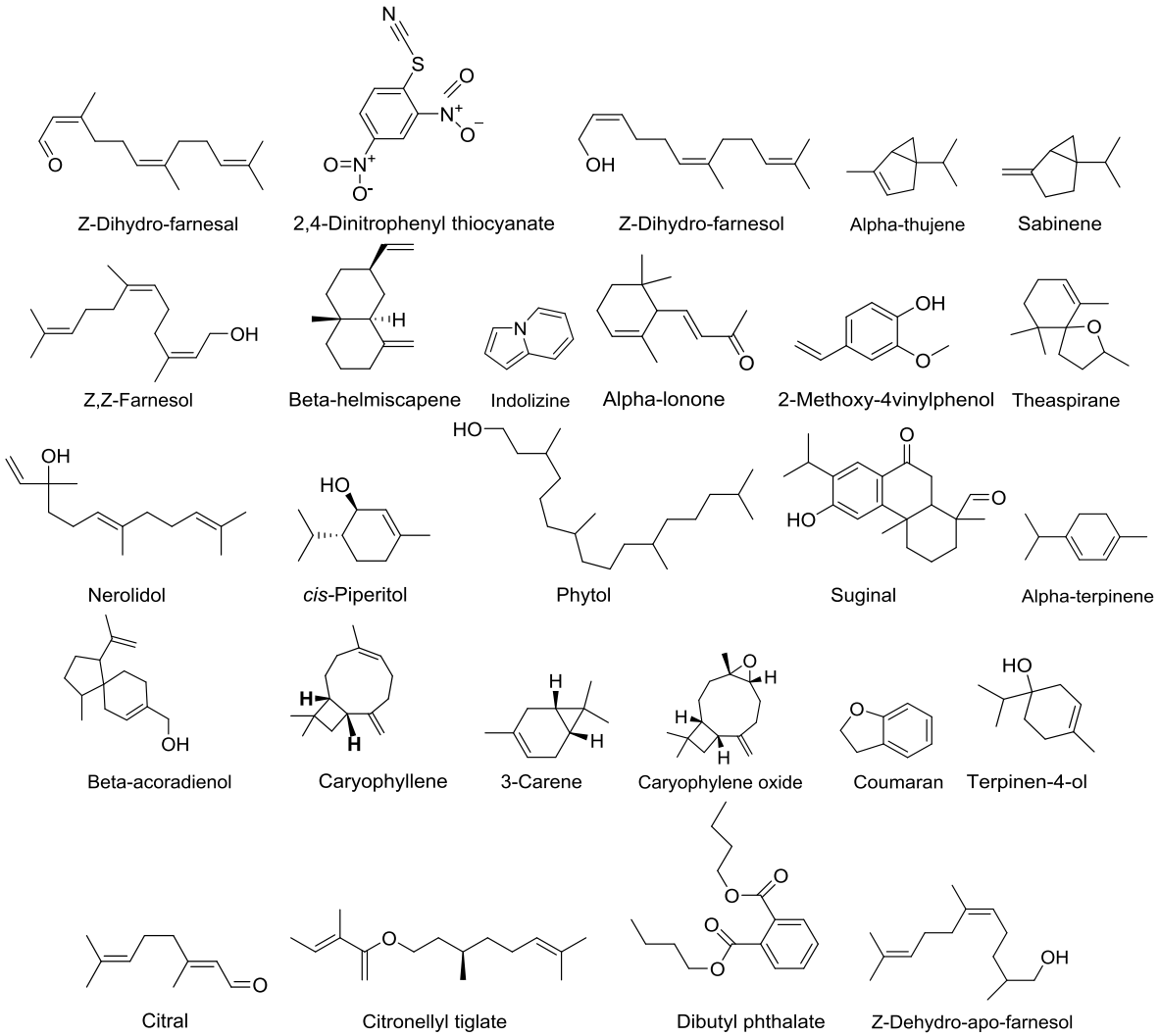
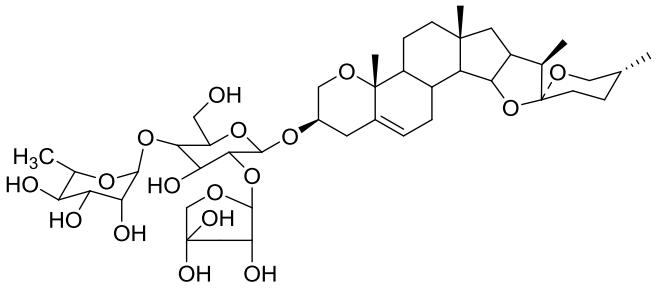


Fig. 2. Distribution of essential oil compounds of *Costus afer* Ker–Grawl





Aferoside A

Fig. 3. Chemical structures of some selected phytocompounds from different parts of *Costus afer*

Table 10. Vitamin compositions of *C. afer* leaf (mg/100 g) [41]

Vitamins	Composition (mg/100 g)
Vitamin A	0.48±0.02
Vitamin D	0.09±0.01
Vitamin E	265.67±5.49
Vitamin B1	0.53±0.03
Vitamin B2	1.28±0.07
Vitamin B3	0.43±0.03
Vitamin B6	0.55±0.04
Vitamin B12	0.07±0.00
Vitamin C	3.27±0.09

Table 11. Mineral composition of *C. afer* leaf and stem Mineral [41]

Mineral element	Composition (mg/100 g)	
	Leaf (mg/kg)	Stem (mg/kg)
Calcium	7.69±1.12	7.92±0.25
Magnesium	4.01±1.25	3.64±1.15
Potassium	1.02±0.34	0.95±0.03
Sodium	1.97±0.12	2.25±1.07
Chromium	0.07±0.01	0.10±0.05
Lead	0.01±0.00	0.02±0.00
Manganese	0.82±0.02	0.75±0.12
Nickel	0.17±0.01	0.12±0.05
Copper	0.44±0.02	0.52±0.11

Table 9 gives the composition of the essential oil of *Costus afer* Ker-Grawl. Sesquilavanduylyl acetate (A: 17.0%) is the most abundant compound, followed by β-Caryophyllene (B: 12.3%), Z,E-Farnesol (C: 9.9%), E-Theaspirane (D: 4.7%), β-Ionone (E: 4.5%), Abietatriene (F: 4. 0%), trans-Piperitol (G: 2.3%), ∆-3-Carene (H: 1.9%), α-Terpinene (I:1.9%), Z,E-Nerolidol (J: 1.6%), β-Selinene (K: 1.5%), Terpinen-4-ol (L:1.2%), Z-Dihydro-farnesal (M:1.1%), sabinene (N: 1.0%). These compounds constitute 64.9% of the composition of the essential oil of plant, the other compounds constitute only 35.1%. The presence of these major compounds such as β-caryophyllene, β-Ionone and α-Terpinene would be the basis of several pharmacological properties such as anti-inflammatory, anti-cancer.... [16].

3.3 Pharmacological Activities of *Costus afer*

3.3.1 Analgesic and anti-inflammatory effects

Being a complex process, inflammation is initiated by several factors related to harmful chemical or physical stimuli or microbiological toxins. The inflammatory response aims to

inactivate or destroy foreign organisms, remove irritants and set the stage for tissue repair [42].

Certain regular occurrences, such as redness, swelling, warmth, and pain usually characterize inflammation, sometimes leading to exudation and loss of function. The process of inflammation involves several inflammatory events and mediators which are potent chemicals found in body tissues, such as prostaglandins, leukotrienes, lymphokines, prostacyclins, and chemokines such as interferon-α (IFN-α), IL-8, IFN-γ, interleukin (IL)-1, histamine, 5-hydroxytryptamine (5-HT) and tumor necrosis factor-α (TNF-α) [43]. According to the modern concept, inflammation is a healthy process resulting from a disturbance or disease. To overcome this problem, various types of safe and effective anti-inflammatory agents are available, such as aspirin and other nonsteroidal anti-inflammatory drugs, and many other drugs are under development. Although steroidal anti-inflammatory drugs and NSAIDs are currently used to treat acute inflammation, these drugs have not been completely successful in curing chronic inflammatory disorders, and most of them carry an increased risk of blood clotting, causing heart attacks and strokes. Reports suggest that nearly 90% of drugs used for inflammation produce drug-related toxicities, iatrogenic reactions, and adverse effects that complicate the treatment process [44]. As a result, there has been a shift in the field of anti-inflammatory treatment from the use of synthetic products to natural therapy. The development of powerful anti-inflammatories from natural products has long been considered. Natural resources provide a rich base for the discovery of new drugs due to their chemical diversity. Medicinal plants, including those particularly used for their aromatic properties (herbs), such as spices and vegetables, are of great importance in primary health care in many developing countries.

The use of aromatic plants depends on the content and composition of their active compounds. Most of these compounds can be described as secondary metabolites, such as terpenoids, carotenoids, phenolic acids, flavonoids, coumarins, glucosinolates, and alkaloids, which are naturally present in plants and act as a protective mechanism against predators, pathogens, and competitors [45]. Some of these compounds, such as phenolic acids, flavonoids, and diterpenes, are known to have potential human health benefits. Africa is blessed with a large number of vegetables, fruits and spices that are consumed for their nutrients or for medicinal purposes. In traditional African medicine, many edible fruits and spices are considered effective in relieving pain [46].

Scientific evidence is mounting that many of these herbs and spices do have medicinal properties that relieve inflammatory conditions. A growing body of research has shown that commonly used herbs and spices, such as cloves, ginger, rosemary, turmeric and garlic, have anti-inflammatory properties that, in some cases, can be therapeutic. Many researchers have focused on spices and vegetables, and a number of species have been studied for their anti-inflammatory and antinociceptive potential [47, 48].

Alkaloids have known anti-inflammatory effects. Flavonoids and phenolic compounds are powerful antioxidants that prevent oxidative cell damage and also have anti-inflammatory, anti-allergic and anti-thrombotic properties. Proanthocyanidins are a type of bioflavonoid with very powerful antioxidant activity. Previous studies have also shown that plant extracts with anti-inflammatory properties may contain phytochemicals with antioxidant activity against deleterious chain reactions triggered by reactive oxygen species associated with inflammation [49].

The hexane fraction of *C. afer* leaves (CAHLF) exhibited a substantial anti-inflammatory activity *in vivo* which could be possibly through inhibition of prostaglandin synthesis and scavenging of perpetuating ROS generated during inflammation. Thus, CAHLF could be considered as an important source of anti- inflammatory compounds for pharmaceutical drug development [50].

Analgesic is used as a painkiller without blocking any nerve impulse conduction, altering sensory perception nor affecting consciousness. Some of the methods employed in evaluating analgesic property include acetic acid-induced writhing, the tail flick assay, and the tail immersion assay [39]. The effects of *Costus afer* Leaf Extract (CALE) and *Costus afer* Stem Juice (CASJ) were significantly ($P<0.05$) different from the negative control group and compared favorably with the effects of Aspirin. The experiments therefore indicate that CALE and CASJ could contain principles with strong antinociceptive properties and raises in the search for new antinociceptive

agents with minimal side effects and high potency for the management of pain related body diseases [51].

The results presented here regarding analgesic and anti-inflammatory experiments seem to provide evidence to support the traditional use of *C. afer* extract for the relief of pain and inflammation in the management of arthritis. Implicitly, the plant could be considered as a drug candidate in the development of drugs for pain and inflammation.

3.4 Antioxidant Activities

The free radical scavenging activity of the extracts with 2,2-Diphenyl-1-picrylhydrazyl (DPPH) using thin layer chromatography and the Ferric Reducing Antioxidant Power (FRAP) were found to be positive. The aqueous extracts of the different parts of the plant had a higher free radical scavenging activity (FRAP) than the other extracts. For DPPH, the methanolic extracts of leaves and rhizomes and the ethyl acetate extract of stems had higher activity than the other extracts of different parts.

Moreover, the inhibition of lipid peroxidation by the aqueous extract (80.60 ± 0.28%) was significantly higher ($p < 0.05$) than the methanolic extract (77.00 ± 0.84%). Nevertheless, methanol and aqueous extracts of *C. afer* possess antioxidant properties as well as bioactive metabolites [17, 52].

3.5 Others Activities

3.5.1 Anti-spasmodic activity

Acetylcholine and histamine doses significantly ($P<0.05$) increased the amplitude of rhythmic contractions in the jejunum, whereas CALE

Table 12. Extraction solvent effect on the antioxidant capacity of different parts of *Costus afer*

Plants parts	Solvent	FRAP (mg/g cat. eqv.)	DPPH (IC_{50})
Leaf	HEX	$138.56 \pm 0.8^{b\alpha}$	$7.69 \pm 0.07^{b\alpha}$
	Ethyl acetate	$123.03 \pm 0.26^{c\upsilon}$	$13.28 \pm 0.43^{b\beta}$
	MeOH	$251.84 \pm 2.19^{a\alpha}$	$0.19 \pm 0.03^{c\alpha}$
	H_2O	$57.76 \pm 0.14^{d\alpha}$	$59.07 \pm 2.72^{a\upsilon}$
Stem	HEX	$114.88 \pm 0.7^{b\beta}$	$7.7 \pm 0.08^{c\alpha}$
	Ethyl acetate	$156.89 \pm 0.68^{a\alpha}$	$0.41 \pm 0.06^{d\alpha}$
	MeOH	$103.04 \pm 1.75^{b\beta}$	$38.94 \pm 0.49^{a\delta}$
	H_2O	$46.93 \pm 0.76^{c\beta}$	$17.23 \pm 0.16^{b\alpha}$
Rhizomes	HEX	$105.3 \pm 0.73^{c\beta}$	$5.10 \pm 0.03^{c\beta}$
	Ethyl acetate	$139.43 \pm 0.37^{a\beta}$	$11.96 \pm 0.0^{b\beta}$
	MeOH	$117.51 \pm 0.52^{b\beta}$	$4.92 \pm 0.2^{c\beta}$
	H_2O	$55.04 \pm 0.35^{d\alpha}$	$40.68 \pm 2.2^{a\beta}$

^{a,b,c,d} *Solvents effect on antioxidant capacity of plant parts. Means with different letters (a, b, c, and d) within a column of the same plant part are significantly different from each other at $p < 0.05$. αβδ compares the antioxidant capacity of plant parts extracted with the same solvent. Means designated with different symbols are significantly different from one another at $p < 0.05$.*

Table 13. IC_{50} concentrations of different fractions of *C. afer* leaf and stem in different antioxidant system *in vitro* [17]

Fractions of *C. afer*	IC_{50}	
	TBARS (0.1-1.0 µg/ml)	LPO (10-100 µg/ml)
Butanol stem	0.68	57.94
Butanol leaf	0.49	47.21
Hexane stem	0.49	51.02
Hexane leaf	0.48	52.19
Ethyl acetate stem	0.40	60.39
Ethyl acetate leaf	0.41	48.40
Aqueous stem	0.37	41.15
Aqueous leaf	0.38	43.90
Gallic acid	0.36	44.40
Ascorbic acid	0.40	44.09

caused a significant (P<0, 05) of basal rhythmic contractions and acetylcholine- and histamine-induced contractions, with 114.3µg/ml CALE inhibiting 2.86µg/ml acetylcholine and histamine by 69.37 and 50.34% respectively. The effects of CALE compare favorably with those of atropine and promethazine and suggest that the extract may contain principles with antispasmodic properties and may be useful in the management of diseases such as diarrhea, incontinence, peptic ulcer, gastrointestinal cramps, gastritis and muscle spasms [52, 53].

3.5.2 Hypoglycaemic activity and Inhibitory activity of carbohydrate hydrolysing enzymes

Costus afer showed a significant hypoglycemic effect (p<0.05) comparable to that of the standard hypoglycemic drug glibenclamide. However, the plant extract did not reduce blood glucose levels in glucose-fed rats. Similarly, a combination of the plant extract and glibenclamide caused a significant reduction in fasting blood glucose in both glucose and non-glucose fed rats. The results validate the use of *Costus afer* as a hypoglycemic plant in indigenous medicine [54].

Hexane, ethyl acetate, methanol and water extracts prepared from the leaf, stem and rhizome of C. afer inhibited α-amylase and α-glucosidase activities. Rhizome extract in ethyl acetate and leaf extract in methanol showed the best inhibitory activity against α-amylase and α-glucosidase (IC_{50}: 0.10 and 5.99 mg/mL), respectively. Kinetic analysis revealed two modes of enzyme inhibition (competitive and mixed) [51].

3.5.3 Antimicrobial activity

The ethanolic extract inhibited all test organisms *S. aureus*, *E. coli, P. mirabilis*, *K. pneumonia* and *P. aeruginosa*. The results had revealed that *Costus afer* inhibited the growth of test organisms *Aspergillus niger*, *Fusarium oxysporium* and *Botryodiploidia theobromae* except *Rhizopus stolonifer*. The *in vivo* results had shown that *C. afer* extract was effective in reducing tuber rot, suggesting that the use of *C. afer* would be useful in the treatment of mycotic infections and in the control of fungal diseases of plants, justifying the use of this plant in the treatment of human and plant diseases [55, 56].

3.5.4 Nephroprotective effect on lead induced kidney damage

Costus afer treatment had significantly (P < 0.05) reversed the decrease in Glutathione Peroxidase (GSH-PX), Glutathione-S-trasferase (GST), Catalase (CAT), Superoxide Dismutase (SOD) activity levels observed in the lead acetate alone group. Similarly, the increase in malondialdehyde (MDA) level in the lead acetate alone group was significantly (P < 0.05) reduced in the *Costus afer* treated groups. There were significant (P < 0.05) decreases in serum sodium (146 ± 2.1 to 133 ± 6.0) and potassium (5.1 ± 0.4 to 4.4 ± 0.3) in the lead acetate-alone group and the treatment group, respectively. There was also a significant decrease (P < 0.05) in serum total protein and albumin levels (67 ± 7.9 to 47 ± 5.0 g/dl) and (45 ± 4.4 to 33 ± 5.5 g/dl) in the lead acetate alone and *Costus afer* treated groups, respectively. Conclusions: Aqueous extract of *Costus afer* leaves may be nephroprotective in albino rats [55, 56].

3.5.5 Cardiac activity and blood pressure coupled with respiration

The pharmacological effect of the total aqueous extract of *C. afer* on cardiac activity and blood pressure coupled with respiration had revealed that *C. afer* at doses between 2.94.10-3 and 4.71.10-2 g/kg body weight (BW) induces a decrease in the amplitude of P and QRS waves as well as heart rate in rabbits. This extract at doses between $2.94.10^{-3}$ and $3.82.10^{-2}$ g/kg body weight (BW) induces hypotension and decreased amplitude of respiratory activity in rabbits. In the presence of atropine (10^{-6} mg/ml), the negative inotropic effect of *C. afer* is abolished. The persistence of the negative chronotropic effect in the presence of this muscarinic cholinergic receptor antagonist also suggests the presence of non-cholinergic cardioinhibitory substances. For concentrations between 10^{-12} and 10^{-6} mg/ml, *Costus afer* induces positive inotropic effects on the isolated rat heart which would be due to the presence of cardiotonic substances. *Costus afer*, at concentrations above 10^{-6} mg/ml, induces negative inotropic and chronotropic effects on the contractile activity of the isolated rat heart. The results of this study would thus suggest that this crude extract would contain cholinomimetic and non-cholinomimetic active principles and adrenomimetic active principles [57].

4. CONCLUSION

The aim of this study was to review the literature on the use, nutritional value, phytochemical and pharmacological activities of *Costus afer* Ker-Gawl. (Costaceae), in order to broaden its spectrum of use in the treatment of inflammation. This has fortunately been demonstrated and proven through the phytochemicals present in *Costus afer* Ker-Gawl. (Costaceae). Flavonoids, alkaloids, phenols and essential oils, provides scientific evidence for its use as antihyperglycemic, hepatoprotective, cardioprotective, nephroprotective, analgesic, anti-inflammatory and antioxidant, and other pharmacological activities. Thus *Costus afer* Ker-Gawl is a good candidate for the research program on screening tropical plants for the development of lead compounds against inflammatory, cardiac and antimicrobial diseases.

This study therefore opens new doors in this field especially, for future work, not only to improve currently used therapies, but also to design and develop new therapies, which are safer, natural and with fewer side effects than previous or currently used synthetic pharmaceutical drugs, which are prepared in laboratories using time-consuming methodologies, toxic solvents and catalysts, with high environmental risk and most of the time with very low yields:

- To our knowledge, no member of the research group has published this topic as a review article.
- This search covered almost all of the reports, with details of the phytochemical and phytopharmaceutical profiles and respective mode of action of some of them.
- This research strongly believes and anticipates that the literature summarized in this area will certainly serve as an important update on *Costus afer* and its use, and also enable researchers to develop new drugs for different therapies including dysmenorrhea.

CONSENT AND ETHICAL APPROVAL

It is not applicable.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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