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Cultivation, Phytochemical Studies, Biological Activities and Medicinal Uses of *Aloe ferox*, Grandfather of Aloes an Important Amazing Medicinal Plant

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Abstract: *Aloe ferox* is an ethnomedicinal and economic plant in India and worldwide. It is a common ingredient in Ayurvedic medicine. To date, many scientific studies have been carried out but a comprehensive review on this plant is lacking. This review aims to cover the cultivation practices and biological activities, the active compounds derived from *Aloe ferox*. Literature survey revealed that the pharmacological effects of *Aloe ferox* range from anti-oxidant, anti-inflammatory, anti-microbial, anti-diabetic, cardiovascular diseases, neurodegeneration to anti-cancer property. Over 130 biological active compounds consisting of fatty acid, sterols, sesquiterpene lactones, flavonoids and carbohydrates have been identified from different parts of the plant. *Aloe ferox* is similar to *Aloe vera* but it has 20 times more nutritional activities. Many of these active compounds were derived from the leaf gel and have been evaluated for a number of biological activities. Despite the encouraging results demonstrated by these studies and the traditional use as nutraceutical agent, analgesic, anti-inflammatory, wound healing, immune modulator, anti-tumor, anti-bacterial, antifungal, antiviral and toxicity of *Aloe ferox* leaf extracts or its derivatives are absent. Thus, a systematic documenting review would provide more insights and spur further research that would lead to production of safer and economical alternative medicine from *Aloe ferox*. In this review we briefly introduced its phytochemical, biological activities, medicinal uses and cultivation practices which can be useful as a potential drug in pharmaceutical industry. The propagation of medicinal plant *Aloe ferox* is vital for sustainable uses in modern world.

Key words: *Aloe ferox,* bio-active compounds, phytochemicals, cultivation practices, medicinal uses

INTRODUCTION

Aloe species can be identified by their characteristic leaf structure and *Aloe* species are generally recognized by their rosettes of succulent leaves and tall, candle-like inflorescences which are also seen in several other succulent genera, such as Agave, *Aloe vera*, the only *Aloe* species not covered by the CITES convention, is propagated worldwide to supply the medicinal and cosmetics industries. South Africa and India have rich heritage of ancient wisdom and their traditional medicinal systems are part of their heritage (Ayurvedavaridhi and Ayurvedavaridhi, 2008). There are over 500 taxa in the genus *Aloe*, concentrated in southern and eastern Africa and Madagascar (McGough, 2004). Twenty two *Aloe* species are listed in CITES (Convention on the International Trade of Endangered Species of Wild Fauna and Flora) Appendix I (Eggli, 2001; McGough, 2004). The remainder of the genus including *Aloe ferox*, excluding *Aloe vera*, is listed in CITES Appendix II (McGough, 2004). *Aloe ferox* is similar to *Aloe vera* but has many times more nutritional and medicinal value than *Aloe vera*. *Aloe ferox* is also known as *Cape aloe*, *Bitter aloe*, *Tap aloe*, *Aloe ferox*, in Africa. Red *Aloe* and Lily of the Desert is a species of *Aloe* indigenous to south Eastern and Western regions of South Africa's Western cape, Eastern cape, free state (Kambizi *et al*., 2005) and it belongs to asphodelaceae.

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There is increased international demand due to its effectiveness, availability and safety in medicinal use, worldwide population of developing countries continues to rely heavily on the use of traditional medicine as primary source of healthcare. Hence, various communities in different parts of the world would use the species of *Aloe* indigenous to their immediate surrounding as medicine. In South Africa various traditional communities and local industries are using a variety of *Aloe* species for example, *Aloe ferox* in the Eastern and Western Cape provinces (Shackleton and Gambiza, 2007) in the treatment of arthritis (Shelton, 1991), skin cancer, burns (Barrantes and Guinea, 2003; Zhang and Tizard, 1996), eczema, psoriasis, digestive problems, blood pressure problems and diabetes (Loots *et al*., 2007).

Aloe ferox originated from South Africa and it was widely distributed throughout the tropics and sub tropics where it grown as ornamental and medicinal plant. It is a grandfather of Aloes, restricted to South Africa and also common species for cultivation. Many plants of *Aloe ferox* grow up to 5 meters tall but there is variability in size over the distribution area of the plants (Shackleton and Gambiza, 2007). The *Aloe ferox* plants can be cultivated widely without any pesticides, herbicides or fertilizers. When the leaves are harvested, the plants are not harmed or destroyed and the cycle of growth begins again from the original plant.

Taxonomy: *Aloe ferox* falls under the scientific classification as follows (DAFF, 2013):

- Kingdom: Plantae
- Clade: Angiosperms
- Clade: Monocots
- Class: Equisetopsida
- Sub class: Magnolidae
- Super order: Lilianae
- Order: Asparagales
- Family: Xanthorrhoeaceae (Liliaceae)
- Sub family: Asphodelodeae
- Genus: *Aloe*
- Species: ferox Mill.
- Chromosome No. 2n = 14

The yellow bitter sap and white gel are present in aloe leaves. Among these gels, the bitter sap lies underneath the green peel and is part of the peel (Wasserman *et al*., 2002). Aloe bitters is largely used in purgatives for the past 200 years. Since 1994 *Aloe ferox* was described and quantified as international trade with a particular focus on the role of European Union (EU). The inner fleshy portion of aloe leaves consists of a mucous material, called aloe gel which is not bitter. It was suggested that the pregnant women not to be taken the bitter sap (Brinker, 1998; Steenkamp and Stewart, 2007) as it can stimulate the uterus. It can pass through the breast milk from mother to baby resulting in colicky babies (Nusko *et al*., 2000).

Vernacular names: *Aloe ferox* has been granted tree status and its national tree number in South Africa is 29.2. The spice name ferox means 'ferocious' and it refers to the spiny leaves.

Common names: Lily of the desert, Cape aloe, bitter aloe, bergaal wyn, Tap aloe, Red aloe.

Local names: Zulu, Xhosa, Sotho-umhalba, Africans- Bitteralwin, Tapaalwyn, English-Bitter Aloe, Red Aloe, French-Aloes du Cap.

Another names: The doctor of the sky, the plant doctor, the plant which cures, the plant miracle, the plant of first aid, the plant of burns, the remedy of harmony, the vegetable Doctor, the green doctor, doctor aloes, the doctor out of pot, the quiet healer, the fountain of youth and Elixir of long life.

Synonyms: *Aloe candelabrum, Aloe berger.*

Botanical description: *Aloe ferox* Mill., is well known as cape aloe or bitter Aloe. It is a single stemmed robust and succulent plant Fig. 1. The height of stem reaches around 10 m tall, leaves reach around 1m in length. The meaning of ferox is ferocious. It refers to the thorny sharp red brownish spines on the leaves. The beautiful bright red or

Fig. 1: *Aloe ferox* with red flowers

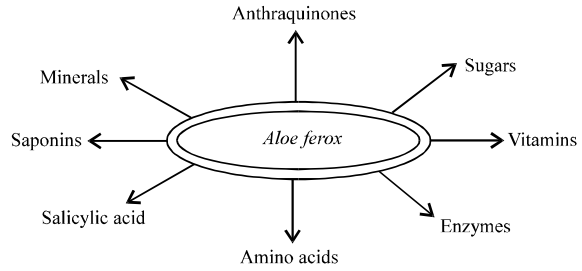

Fig. 2: Components of *Aloe ferox*

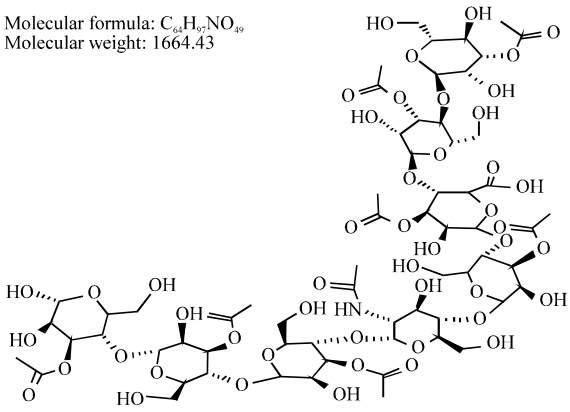

Fig. 3: Chemical structure of Acemannan

orange flowers are bloomed between May and August. They attract birds and numerous insects. *Aloe ferox* has an extensive distribution in South Africa (Street and Prinsloo, 2013). A number of herbs belonging to the genus Aloe are noted for their medicinal and cosmetic benefits in traditional system of medicine (Maduna, 2006). Aloe comprises about 450 species in Africa and Arabia, of which 315 occur in mainland Africa, 100 are endemic to Madagascar or the Indian Ocean islands (including the former Lomatophyllum) and 50 occur in Arabia. Inflorescence arranged in dense, large and elongated racemes 50-80 cm long peduncle with 5-8 spreading branches bracts broadly ovate, 2-5 mm×2-4 mm. Flowers can be described as bisexual, regular, 3-merous; pedicel 1-1.5 cm long tubular, 2.5-3.5 cm long, lobes 6, 12-17 mm long, red colour, sometimes white or yellow stamens 6, exerted ovary superior, 3-celled, style filiform, stigma head-shaped, exerted. Fruit an ovoid capsule up to 3 cm long, dehiscing loculicidally, many seeded. Seeds 9 mm long, broadly winged. Leaves are fleshy, lance shaped, bearing racemes or panicles of tubular or cylindrical flowers (Protologue, 2013).

Nutritional values: So far, more than 130 biological active compounds were isolated from *Aloe ferox* (Kambizi *et al*., 2005; Mabusela *et al*., 1990). The *Aloe ferox* leaf contains substances (Fig. 2) such as minerals, amino acids, polysaccharides, vitamins, glycosides, glycoproteins, enzymes, anthraquinones, chlorophyll, lignin, saponins (Alessandro and Stefano, 2005), sterols and other plant chemicals with numerous medicinal activities (Nema *et al*., 2013; Shackleton and Gambiza, 2007; Dagne *et al*., 2000). Acemannan (Fig. 3) is an anticancer agent derived from *Aloe ferox* leaf gel extract (Nema *et al*., 2012).

Growth and development: It can grow to 10 feet (3.0 m) in height and can be found in grassy fynbos, on rocky hills and on the edges of the Karoo. It was observed their growth at selected sites in the Makana region of the Eastern Cape (Shackleton and Gambiza, 2007). Due to environmental conditions, the physiology of plant may differ from area to area. Aloe leaves are thick and fleshy, arranged in rosette shape with reddish-brown spines, on its margins contains smaller spines on both upper and lower surfaces (Floridata, 2009). Its flowers are orange or red and stand between 2 and 4 feet (0.61 and 1.2 m) above the leaves. Aloe species follow the Crassulacean Acid Metabolism (CAM). Minimizing of water loss in CAM plants caused by closed stomata during day time resulting photosynthesis to fix CO_2 at night. This, plus their succulent leaves and stems and the presence of a thick cuticle, makes them well adapted to dry conditions. Severe drought, though, stops exudates production. It has a stem surrounded with a persistent layer of dead leaves (Bond, 1983) that insulate the stem in the case of bush fires. Harvesting of *Aloe ferox* leaves for medicinal purposes could thus result in significant mortality due to fires. The flower morphology of *Aloe ferox* suggests pollination by birds. However, honey bees also play a role in the pollination. It is self incompatible and only a few flowers per raceme flower simultaneously. The stamens produce pollen in the morning and wither in the afternoon, whereas the style is exerted on the second day of anthesis. It occurs in land with moderate or less rains and dry, less fertile soil, water required moderately during the growing season and springy in dormant stage. Sow seed at 70 °F or separate offsets in late spring and plant in cactus potting mix.

Ecology: *Aloe ferox* is one of the dominant species in the 'succulent bush land' vegetation in South Africa. It grows in a wide range of climatic conditions. It is especially abundant on arid rocky hill sides up to 1000 m altitude, where mean temperatures range from 27-31°C. Annual rainfall ranges from 50-300 mm. Though the root system is shallow, the plant can grow under dry conditions. Water logging should be avoided and it thrives on well drained.

Management: Commercial cultivation becomes a profitable option now that not only the exudates but also the gel has become interesting. Details on cultivation have not been published.

Cultivation practices: *Aloe ferox* prefers dry tropical climates, sandy loamy soils, open areas, full sun *Aloe ferox* (Nema *et al.,* 2013) and moderate watering with good drainage system. *Aloe ferox* plants are propagated mainly from seed and head cuttings (Sahu *et al*., 2011). The plants are sowed one meter apart from each other in rows and columns. It takes about 4-5 years for the plants to reach the first harvest, from the seed stage. At the time of harvest, each leaf weighs about 1.5-2 kg.

Harvesting: Harvesting of leaves from wild plants is thought to be sustainable. *Aloe ferox* exudates is often collected by cutting off the leaves transversely close to the stem and positioning them in such a way that the exudates drains into pots, tubs, vessels or even a simple canvas placed over a depression in the ground. The exudates may also be obtained by squeezing the leaves or by warm or cold water retting. In South Africa *Aloe ferox* is preferably tapped during the rainy season, because then the exudates are more abundant but tapping is also carried out in other periods of the year, except for the driest months. The leaves are usually cut in the morning and it takes 4-5 h for the exudates to drain from a pile of leaves. Only older leaves are cut younger ones and growing tips are spared.

Handling after harvest: Collected exudates are usually concentrated by boiling and then cooling. On cooling, a solid, amorphous extract is formed and this constitutes the drug. Its appearance varies with the concentration process used. If the exudates have been concentrated slowly, in the sun or over a low fire, the cooled extract is opaque, waxy and liver colored (hepatic aloe) and aloin crystals are visible under the microscope. An option for adding value is to produce dried and ground leaf powder. After the leaf exudates are extracted, the leaves are pulped and squeezed dry under high pressure. The liquid is settled and treated with chemicals to flocculate the jelly fraction. The gel can be obtained by removing the outer tissues of the leaf. In Aruba, gel is obtained by cutting open the leaves lengthwise and scraping the gel from the leaf blade. The youngest leaves (<25 cm) are not suitable because of the small amount of gel but the leaves should not be too old, because gel quantity and quality may decline. The dead leaves of *Aloe ferox* have an insulatory function and are adaptive prone habit and fire survival in South African tree aloes (Bond, 1983).

Yield: Two tons of *Aloe ferox* leaves yield about 1 kg of gel powder which is a higher ratio than for *Aloe vera* (Protologue, 2013).

Diseases and pests: Aloe species are susceptible to some of the worst plant disease in the succulent plant world, in this article we will take a look at the diseases that afflict Aloes and examine the ways in which we can prevent Aloe ailments and methods on how to cure them.

Aloe cancer: It is a viral infection also well known Witches Broom. Aloe cancer is spread via mites and causes unsightly growths. In case of rare aloes you can cut out infected areas but the plant must be isolated as it is highly probable that neighboring aloes will be infected. *Aloe* scale or white scale: *Aloe* scale or white scale is are sap suckers approximately 1-2 mm in length and they are white in color. White Scale starts of as a small infestation on aloe leaves but it can turn into a serious infestation in a short period of time that will in all probability result in the death of the *Aloe*.

Ants and aphids: Ants on their own do not cause any damage to aloes but due to their propensity for all thing sweat they can cause severe damage when they partner up with mealy bugs and aphids. Ants and aphids have a symbiotic relationship; the ants afford protection to the mealy bugs in exchange for sweet and sticky honeydew that they excrete.

Rot: Rot in aloes is usually caused by humans as inexperienced growers tend to over water them. It can also be caused by *Aloe* beetle and mealy bugs etc.

Snout beetle or aloe beetle: The presence of adult snout beetles which feed off on *Aloe* leaves can be detected by the presence of circular lesions with a transverse slit in the center. Snout Beetles lay their eggs at the base of *Aloe* leaves, the larvae, after hatching; bore into the stem just below the crown which results in the death of the plant.

***Aloe* sap crystals:** Leaves are stacked in a circle around two to three hundred, cut surfaces facing inwards and overlapping, so that the sap drains and collects in the hollow (bellow middle). After some hours the sap of several draining sites are collected and processed to produce bitter crystals and bitter powder. The bitter sap is poured in a metal drum and then heated over an open fire. The contents are continuously stirred while hot, until the volume is reduced by approximately half. The warm sap is then decanted into a tin and allowed to cool and

solidify. The solid hard block can be broken and splintered into crystal of varying sizes. The leaves, from which the bitter sap has been tapped, are then further processed to make use of the aloe gel. The crushed leaves are used to prepare an aloe jelly. A wholesome fruit drink is made from this and the jelly is also a much sought after component in cosmetic products (Anonymous, 2013; Gerrylocs, 2011).

Medicinal uses: The yellow bitter sap of *Aloe ferox* is used as laxative and white *Aloe* gel is used in health drinks and skin care products. When compared to *Aloe vera,* it has more amino acids and polysaccharides. The sap is toxic to pregnant and breast feeding mothers (Find Me a Cure, 2011). In Southern Africa Cape aloe, is used as a purgative in human and veterinary medicine, ophthalmia and syphilis. The gel used as a general refrigerant. It is further more used as a shampoo to promote hair growth and against dandruff and as a cosmetic to improve the complexion and to smooth the skin. It is also used as a hydrating and skin-protecting agent in creams and liquids such as shaving cream, lip balm, sun lotion and healing ointments (Protologue, 2013). Numerous scientific studies on aloe gel are demonstrating its analgesic, anti-inflammatory, wound healing, immune modulating and anti-tumor activities as well as antibacterial, antiviral and antifungal properties (Nema *et al*., 2013). The aloe juice has been shown to decrease cholesterol (Nema *et al*., 2013) and triglycerides while demonstrating anti diabetic activity. Its medicinal properties can be attributed (Nema *et al*., 2013) to the synergistic effect of the combined nutritional elements producing a more powerful effect than the individual components. Analgesic activity (Shelton, 1991) antiinflammatory and oxidative stress (Devaraj and Jialal, 2006; Fawole *et al*., 2010), wound and burn healing (Chithra *et al*., 1998; Jia *et al*., 2008), immune modulating (Nema *et al*., 2013; Zhang and Tizard, 1996; Strickland, 2001), antitumor/cancer activities (Saito, 1993; Bradford and Awad, 2007), antimicrobial activity (antiviral, antibacterial, antifungal) (Reynolds and Dweck, 1999; Soeda *et al*., 1966), antidiabetic, (Bunyapraphatsara *et al*., 1996; Lichtenstein and Deckelbaum, 2001; Loots *et al*., 2011; Normen *et al*., 2000; Jones *et al*., 1999), skin protecting (Syed *et al*., 1997), psoriasis control (Syed *et al*., 1996), liver damage controlling (Kuo *et al*., 2002) HIV/AIDS treatment (Yamamoto, 1973), antiseptic (Okyar *et al*., 2001), antiulcer (Koo, 1994; Wang *et al*., 1998) antioxidant activity (Rice-Evans, 2004), cardiovasicular disease (Patch *et al*., 2006), tuberculosis and bronchitis (Ferro *et al*., 2003).

Internal uses: Aloe juice appears to be safe and there is no reported toxicity and toxicological evaluation of aqueous extract of *Aloe ferox* Mill was reported (Wintola *et al*., 2010, 2011). The mucilage in the *Aloe* juice may interfere with the absorption of other oral medications taken concurrently. Overdose of aloe bitter sap can cause severe diarrhea and intestinal cramping due to the presence of anthraquinones. Internal use of aloe bitter and anthraquinones can lead to dehydration, potassium loss in patients taking corticosteroids or thiazide diuretics, potentiate digitalis and other cardiac glycosides due to low potassium levels and intestinal dependence on laxatives. *Aloe* bitters is not recommended for people (Nusko *et al*., 2000) with intestinal inflammation, intestinal obstruction, (e.g., Crohn's disease, ulcerative colitis) appendicitis and abdominal pain of unknown origin. It is clinically proven that the use of anthranoid laxatives, even in the long term, does not cause cancer (Nusko *et al*., 2000). Aloe gel is also use for the preparation of aloe bitter powder, *Aloe* drinks, *Aloe* bitter crystals, cosmetics, hair and skin care products.

Phytochemical properties: Phytochemicals and their quantities identified which are included various phenolic acids or polyphenols are given in Table 1. (Liu, 2002; Herraiz and Galisteo, 2004; Azam *et al*., 2003). The exudate of *Aloe ferox* contains 15-40% anthrone 10-C-glucosides (anthraquinone derivatives) such as hydroxyaloins and aloin. Aloin is a mixture of the stereoisomers aloin a (barbaloin) and aloin B (isobarbaloin). Furthermore, the exudate contains the pyrone derivative aloenin and free and glucosylated 2-acetonyl-7-hydroxy-5-methylchromones. (e.g., aloesone, furoaloesone, *Aloe* resin A, *Aloe* resin B (aloesin) and aloeresin C). *Aloe ferox* also contains glycosylated feroxidin (a tetralin) and feralolide (a dihydroisocoumarin). Aloin is an inactive laxative compound, it becomes an active aloe emodin anthrone by Eubacterium sp. and responsible for laxative properties. In 2002 the United States Food and Drug Administration withdrew the 'Generally Recognized as Safe and Effective (GRASE)' status for over-the-counter drugs based on aloe exudates. Anthraquinone containing laxatives such as aloe may play a role in colorectal cancer as they have genotoxic potential and tumorigenic potential in rodents. Aloe emodin, chrysophanol and aloin A, all isolated from *Aloe ferox* leaf extract, have significant antibacterial activity in vitro. Aloeresin A and B both reduce the oedematous response induced by croton oil in the mouse ear by 40%. Aloeresin B also modulates melanogenesis

Table 1: Concentrations of Identified compounds from lyophilized *Aloe ferox* leaf gel (LGE) and 95% Ethanol Leaf Gel Extract (ELGE) using GC-MS

	Concentration (ppm)		
Compounds	LGE	ELGE (per dry mass LGE)	ELGE (per dry mass ELGE)
Phenolic acids/polyphenols			
Phenol	15.37	38.87	2.60×10^{3}
Gentisic	1.99		
Vanillic	60.27	24.57	8.5×10^{3}
Homovanillic	19.66	14.36	5.0×10^{3}
o-hydroxycinnamic	56.21		1.6×10^{4}
Protocatechuic	169.42	45.56	
3, 4-dihydroxyphenylacetic	8.54		
5-methoxyprotocatechuic	2.94		
Syringic	26.59		
Sinapic	35.94		
p-coumaric	453.38		
Caffeic	13.84		
Isoferulic	53.12		1.5×10^{3}
Ferulic	89.76	4.43	
4-methoxycinnamic	2.18		
Aloe emodin	87.79		
4-phenyllactic	11.83		1.2×10^{4}
4-ethylphenol	10.15	33.25	
p-toluic	841.63		
Hydrocinnamic	37.68		1.8×10^{4}
p-salicylic	189.54	51.74	
Benzoic	880.36	5506.50	1.9×10^{6}
Phenylpyruvic		6.56	2.3×10^{5}
Mandelic	9.83	84.37	2.9×10^{4}
Phenylpropionic		26.55	9.2×10^{3}
m-hydroxymandelic		141.93	4.9×10^{4}
Phenylpyruvic		6.58	2.3×10^{3}
Hydroxyphenylacetic	113.56	45.34	1.6×10^{4}
Pyrocatechuic	4.67		
Hydro-p-coumaric	15.63		
6, 7-hydroxycoumarin	38.40		
Alkanes			
1, 3-dihydroxybutane	10.48	10.77	3.7×10^{3}
Hexacosane		6.11	2.1×10^{3}
Pyrimidines			
Uracil	697.65		6.3×10^{4}
Thymine	429.33	181.65	
Indoles			
Indole-5-acetic acid	11.61		
Indole-3-acetic acid	2.88		
Hexahydrobenzoindole		20.59	7.1×10^{3}
5-indole carboxylic acid		12.09	4.2×10^{3}
Alkaloids			
Hypoxanthine	28.41		
Xanthine	1333.2		
Sterols			
Cholestanol	24.82	13.42	4.6×10^{3}
Campestrol	13.73		
β-sitosterol	1602.7		
Stigmasterol	69.34		
Alcohols			
2-butanol	13.97		6.8×10^{4}
1-propanol	161.16	196.66	
2, 3-butanediol	339.28		1.4×10^{4}
2-methyl-1, 3-propanediol	355.58	39.14	
Benzyl alcohol	163.43	305.66	1.1×10^{5}
2, 3-pentanediol	8.82		
Glycerol	342.75		
Octadecanol	3.76		
Phenylethanol	87.31		
Aldehydes			
Benzaldehyde	57.46	73.57	2.5×10^{4}
m-tolualdehyde	18.46		

Table 1: Continue

Compounds	Concentration (ppm) LGE	ELGE (per dry mass LGE)	ELGE (per dry mass ELGE)
Organic acids			
Isovaleric	150.40	151.34	5.2×10^{4}
Lactic	149.84	204.92	7.1×10^{4}
Glycolic	92.40		
Pyruvic		88.86	3.1×10^{4}
Furoic	59.23		
3-hydroxypropionic	1.36		
2-hydroxyvaleric	24.13	80.52	2.8×10^{4}
Cyclohexanone-3-carboxylic	1.55		
3-hydroxyisovaleric	41.53	225.97	7.8×10^{4}
3-methyl-1, 3-hydroxybutanoic	21.59		5.7×10^{3}
Methylbenzyl acetic		16.52	
2-hydroxycaproic	6.78		
Phosphoric		342.11	1.2×10^{5}
Methylcrotonic		7.30	2.5×10^{3}
2-ketoisovaleric	0.63	58.62	2.1×10^{4}
3-methylglutyric		1005.90	3.5×10^{5}
Succinic	385.10	118.77	4.1×10^{4}
2-methylsuccinic	63.94		
Picolinic		280.80	9.7×10^{4}
Methylmalic	22.14		
Malic	47.52		
3, 4, 5-trihydroxypentanoic	20.10	5.79	2.0×10^{3}
D-ribonic	7.09		
2-hydroxyglutyric		20.21	7.0×10^{3}
3-hydroxy-3-methylglutyric		20.66	7.2×10^{3}
2-ketoglutyric		17.25	6.0×10^{3}
Tartaric		18.82	6.3×10^{3}
Suberic	12.19		
3-hydroxypicolinic	61.82		
Isonicotinic	40.68		
Hydantoinpropionic		15.15	5.2×10^{3}
2-hydroxybutyric		2.40	829.92
3-hydroxybutyric		71.65	2.5×10^{4}
Fatty acids			
Lauric (C12:0)	0.33		
Myristic (C14:0)	0.75		
Pentadecenoic (C15:0)	1.14	1.71	5.91.32
Palmitoleic (C16:1)	1.35	0.19	65.70
Palmitic (C16:0)	45.55	0.20	69.16
Stearic (C18:0)	3.56	0.83	287.01
Linoleic (C18:2 n-6)	104.06	0.42	45.24
Oleic (C18:1)	0.17		
Linolenic (C18:3 n-3)	1.53		
Erucic (C22:1 n-9)	0.90		
Nonadecenoic (C19:0)	0.14		
Arachidic (C20:1)	0.73		
Heneicosanoic acid (C21:0)	0.50		
Behenic (C22:0)	2.89		
Tricosanoic (C23:0)	3.08		
Lignoceric (C24:0)	9.03		
Pentacosanoic (C25:0)	2.87		
Dicarboxylic acids			
Azelaic	0.03		
Undecanedioic	0.04		
2-hydroxyadipic		6.72	2.3×10^{3}
Ketones			
4, 6-dimethyl-2-heptanone	40.91		
Acetophenone	8.06		
2, 4-dimethyl-4-heptanone	129.50		
Heptanone		177.40	

via competitive inhibition of tyrosinase, thus showing promise as a pigmentation-altering agent for cosmetic or therapeutic applications (Mabusela *et al*., 1990).

Biological activities: *Aloe ferox* plant has a greater concentration of biologically active compounds (Reynolds and Dweck, 1999; Choi and Chung, 2003;

Chen *et al*., 2012). Its healing properties are much more powerful than those of the *Aloe vera* plant.

The presence of the antioxidant polyphenols, alkaloids and indoles, the *A. ferox* leaf gel shows antioxidant capacity as confirmed by FRAP analyses and ORAC. Both analytical methods used show the non flavonoid polyphenols to contribute to the majority of the total polyphenol content. Due to its phytochemical composition (Magwa *et al*., 2006), *Aloe ferox* leaf gel may show promise in alleviating symptoms associated with or prevention of cardiovascular diseases, cancer, neurodegeneration and diabetes (Loots *et al*., 2007: O'Brien *et al*., 2011).

Geographical distribution: *Aloe ferox* is indigenous in South Africa. From the Dutch East India Company's garden in the cape it was distributed throughout the tropics and subtropics, where it is grown as an ornamental and medicinal plant. Although not treated or mentioned in regional floras, its occurrence in several countries of tropical Africa is probable.

Genetic resources and breeding: Aloe species are potentially at risk of extinction as a result of plant collection from the wild. *Aloe ferox* is cultivated widely as an ornamental. Harvesting from the wild is still considered sustainable but warrants monitoring. An export permit is compulsory because apart from *Aloe vera*, all Aloe species are listed in the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) Appendices (Knapp, 2006). *Aloe ferox* does not produce suckers but can be propagated by seed and planting of the tops of old plants. Plant regeneration from root and embryo tissue is successful as well.

Breeding: There is no existed information on *Aloe ferox* breeding programmes. Therefore an enormous scope is required for breeding of *Aloe ferox* in future (Protologue, 2013).

Prospects: *Aloe ferox* is a potential crop in arid regions. It will remain beneficial as a household remedy. Fresh gel can easily be prepared and applied to wounds. In its use as a laxative, however, there is a tendency for the drug to be replaced by other laxatives such as those from *Plantago* spp. The gel industry has a bright future. Other Aloe species producing suckers, such as *Aloe turkanensis* Christian and *Aloe flexilifolia* Christian from East Africa, may prove better candidates for commercial cultivation.

Production and International trade: Though considerable quantities of 'Cape aloe' are marketed and used locally, most of the exudates produced in South Africa are exported. Total legal harvest is approximately 400 tonnes per year, although an additional 300 tonnes is presumed to go undocumented. Exports are destined for Europe, Asia and North America, with the main importing countries being the United States, Japan and Germany. Production of *Aloe ferox* gel has been hampered by lack of processing facilities in South Africa. Most gel is bought by the cosmetic industry which demands high quality. *Aloe ferox* products have less demand unlike that of *Aloe vera* products. The products of *Aloe ferox* are merely confined to South Africa, United States and few European Countries. Asian markets are mainly dominated by *Aloe vera* products.

FUTURE PROSPECT

Several investigators reported significant medicinal potential of different extracts of *Aloe ferox* and their wide therapeutic activities against numerous illnesses. These evidential properties indicate the importance of this plant for further studies directed to drug development. However, most of the studies were conducted with extracts and there is a lack in isolation of bioactive compounds as well as toxic studies. Recent studies unraveled the anti-cancer activity of *Aloe ferox* extract which revealed another aspect of its potential to be investigated in future studies. Likewise, leukemia and HIV activities could be further explored. Advanced molecular approaches, such as molecular docking studies can contribute towards plant based drug development in the future.

CONCLUSION

Numerous scientific investigations have indicated high medicinal potential of *Aloe ferox* in many diseases (Fig. 4). Thus, there is a definite requirement for further studies, both clinical and on the bench for further development of extracts or bioactive compounds isolated from *Aloe ferox*. Improvement of medicinal chemistry methods could provide the opportunity to further evaluate the natural compounds and to investigate their biosynthetic pathways. Despite these facts, clinical trials using extracts or bioactive compounds are less present, possibly due to mass production issues or lack of

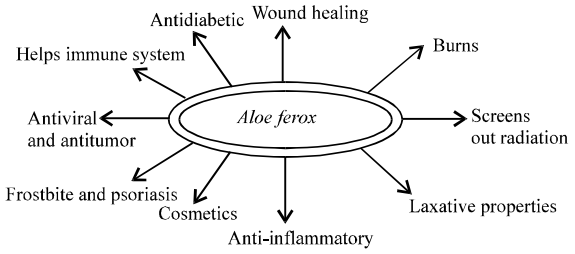

Fig. 4: Medicinal uses of *Aloe ferox*

mechanistic and toxic studies to understand its pharmacological effects. The majority of plants used for medicine are harvested from the wild. This results in serious problems like depletion of resources, extinction of rare species, insufficient supplies, seasonal collections, incorrect identification and adulterations in dried materials, etc. These results support the current use of *Aloe ferox* by both industry and traditional healers for the treatment of the above-mentioned diseases. However, further clinical trials regarding these claims are necessary before accurate conclusions regarding these heath benefits can be made. High yielding plants may be selected and propagated for commercial cultivation by breeding techniques. In South Africa, the aloin content of the leaf exudates was found to differ markedly between provenances. Many Aloe species hybridize in the wild if their area of distribution and period of flowering overlap, and it is easy to produce hybrids in cultivation. The scope for breeding and selection is therefore enormous. Tissue culture techniques for micro-propagation are being used profitably to overcome such problems in various crops, ornamental and horticulture plants. Thus, these findings support the local uses of the plant extract in different infectious diseases in the world. This review study provided the evidence based information to the future scientists for qualitative research and for isolation and characterization of bioactive compounds.

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