A Synthesis and Review of Medicinal uses, Phytochemistry and Pharmacological Properties of *Maerua crassifolia* Forssk. (Capparaceae)

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Abstract: *Maerua crassifolia* Forssk. is an evergreen tree widely used as traditional medicine throughout its distributional range in the Sahel region, peninsular Arabia east to Pakistan, east and west Africa. This study is aimed at providing a critical review of medicinal uses, phytochemical and pharmacological properties of *M. crassifolia*. Documented information on medicinal uses, phytochemical and pharmacological properties of *M. crassifolia* was collected from several online sources such as Scopus, Google Scholar, PubMed and Science Direct, and pre-electronic sources such as book chapters, books, journal articles and scientific publications obtained from the university library. The articles published between 1964 and 2020 were used in this study. This study revealed that the bark, fruit, leaf and twig infusion and/or decoction of *M. crassifolia* are mainly used as ethnoveterinary medicine, and traditional medicine for cephalalgia, headache, fever, malaria, wounds, skin infections, toothache and gastro-intestinal problems. Phytochemical compounds identified from the species include alkaloids, amino acids, betaines, cardiac glycosides, fatty acids, flavonoids, lignan glucosides, phenolics, quaternary ammonium compounds, saponins, steroids, tannins and terpenoids. The *M. crassifolia* extracts exhibited antibacterial, anti-diarrhoeal, analgesic, anti-inflammatory, antioxidant, antiplasmodial, antiprotozoal, antitrypanosomal, antipyretic and cytotoxicity activities. *Maerua crassifolia* should be subjected to detailed phytochemical, pharmacological and toxicological evaluations aimed at correlating its medicinal uses with its phytochemistry and pharmacological activities.

Keywords: Capparaceae, ethnopharmacology, indigenous knowledge, *Maerua crassifolia*, traditional medicine.

INTRODUCTION

Maerua crassifolia Forssk. is an evergreen tree belonging to the Capparaceae or caper family. The synonyms of *M. crassifolia* include *M. hirtella* Chiov., *M. meyeri-johannis* Gilg, *M. rigida* R. Br., *M. uguenensis* Gilg and *M. uniflora* Vahl. [1,2]. *Maerua crassifolia* is a small, spreading and much-branched tree growing up to ten metres in height [3,4]. The bole of the species is stunted and twisted with smooth bark and scaly on older trunks. The leaves are alternate on young twigs and clustered on older branchlets, simple and entire, oblanceolate to elliptic in shape. The flowers are axillary and solitary, borne in terminal spikes or clusters. The fruit is brown in colour, oblong or cylindrical capsule, that is irregularly constricted between the seeds. *Maerua crassifolia* has been recorded in the Sahel region, peninsular Arabia east to Pakistan, east and west Africa [5-10]. The species has been recorded in dry savanna, deciduous bushland, thickets and semi-desert scrub near rivers at an altitude ranging from sea level to 1620 m above sea level [4]. *Maerua crassifolia* is one of the important medicinal plants in tropical Africa and the species is included in the book "plant resources of tropical Africa 11(2): medicinal plants 2", a photographic guide to the most commonly used traditional medicines in tropical Africa [11]. The species is also used beyond its natural distributional range. For example, the Senegalese migrants living in Turin, Italy use the twigs of *M. crassifolia* against halitosis [12]. The bark of *M. crassifolia* is widely used in the Sahel region to purify and reduce the turbidity of water [3,13]. The leaves of *M. crassifolia* are consumed as a leafy vegetable in Burkina Faso, Chad, Ethiopia, Kenya, Mali, Mauritania, Niger and Nigeria and Sudan [14-24]. The flowers and fruits of *M. crassifolia* are consumed in Algeria and the Sahel region [4,16,25], and the species is also important for bee forage in Oman [26]. The fresh and dried leaves of *M. crassifolia* are traded locally in the Sahel region [4]. The leaves and shoots of *M. crassifolia* are browsed by wild and domesticated animals in Kenya and the Sahel region [27-32]. The roots, shoots and stems of *M. crassifolia* are used as toothbrushes in the Sahel region, particularly in Morocco and Algeria [3,4,16,33,34]. *Maerua crassifolia* is an important plant species in the Sahel region and the species could be used in land rehabilitation programmes in degraded landscapes in the region [35,36]. It is, therefore, within this context that this review was undertaken aimed at reviewing the medicinal uses, phytochemical and pharmacological properties of *M. crassifolia* so as to provide baseline

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data required in evaluating the therapeutic potential of the species.

Medicinal uses

The bark, fruit, leaf and twig infusion and/or decoction of *M. crassifolia* are mainly used as ethnoveterinary medicine, and traditional medicine for cephalalgia, headache, fever, malaria, wounds, skin infections, toothache and gastro-intestinal problems (Table **1**; Figure **1**). Other medicinal applications that are recorded in at least two countries and supported by at least two literature records include the use of bark, fruit, leaf and twig infusion and/or decoction as protective charm and purgative, and traditional medicine for abdominal pain, diabetes, jaundice and respiratory problems (Table **1**). In Mali, the leaf ash of

Table 1: Medicinal uses of *Maerua crassifolia*

Medicinal use	Part used	Country	Reference
Abdominal pain	Leaves	Mali and Mauritania	[37,38]
Abdominal pain	Leaf ash mixed with fruits of *Capsicum annuum* L. and *Cuminum cyminum* L.	Mali	[37]
Appetite loss	Leaf ash mixed with fruits of *C. annuum* and *C. cyminum*	Mali	[37]
Cephalalgia and headache	Bark and leaves	Algeria, Egypt and Morocco	[33,40,43,44]
Colic	Leaves	Oman	[41,42]
Diabetes	Leaves	Morocco	[45]
Diabetes	Leaves mixed with gum of *Senegalia senegal* (L.) Britton	Mauritania	[38]
Fever and malaria	Bark and leaves	Algeria, Egypt, Nigeria, Oman, Saudi Arabia and Sudan	[3,4,13,23,25,33,40,43,46-48]
Fever and malaria	Leaf ash mixed with fruits of *C. annuum* and *C. cyminum*	Mali	[37]
Malaria	Leaves mixed with those of *Hibiscus sabdariffa* L.	Mali	[37]
Fracture	Leaves mixed with those of *Lawsonia inermis* L.	Oman	[39-42]
Gastro-intestinal problems (constipation, diarrhoea, epigastric, gastralgia, indigestion and stomach complaints)	Bark, fruits, leaves and twigs	Algeria, Egypt, Ghana, Mali, Mauritania, Morocco, Nigeria, Oman and Saudi Arabia	[3,4,23,33,37,38,40-44,49-52]
Halitosis	Twigs	Italy	[12]
Heart diseases	Leaves	Mali	[37]
Jaundice	Fruits and leaves	Mali and Mauritania	[4,37,38]
Lipido	Bark and leaves	Tanzania	[53]
Poor memory	Leaves	Senegal	[12]
Protective charm (good luck and protection against witchcraft)	Twigs	Egypt and Kenya	[14,54]
Purgative	Leaves	Algeria and Morocco	[3,4,25,33,44]
Respiratory problems (asthma and colds)	Leaves	Mali and Mauritania	[37,38]
Rheumatism	Bark and leaves	Morocco and Sudan	[52,55]
Scorpion stings	Fruits and leaves	Algeria	[25]
Skin infections (boils, burns, infected hairy skins, itching and scalp care)	Bark and leaves	Egypt, Morocco and Nigeria	[4,13,23,34,40,43,44,52]
Tetanus	Leaves	Senegal	[12]
Toothache	Bark and leaves	Algeria, Egypt, Mauritania, Morocco and Saudi Arabia	[13,25,33,38,40,43,50-52]
Wounds	Bark, leaves and stems	Egypt, Morocco and Sudan	[4,34,39,40,44,52,56]
Ethnoveterinary medicine (diarrhoea, eye problems, ticks and wounds)	Bark and leaves	Ethiopia, Kenya, Morocco and Niger	[4,57,58]

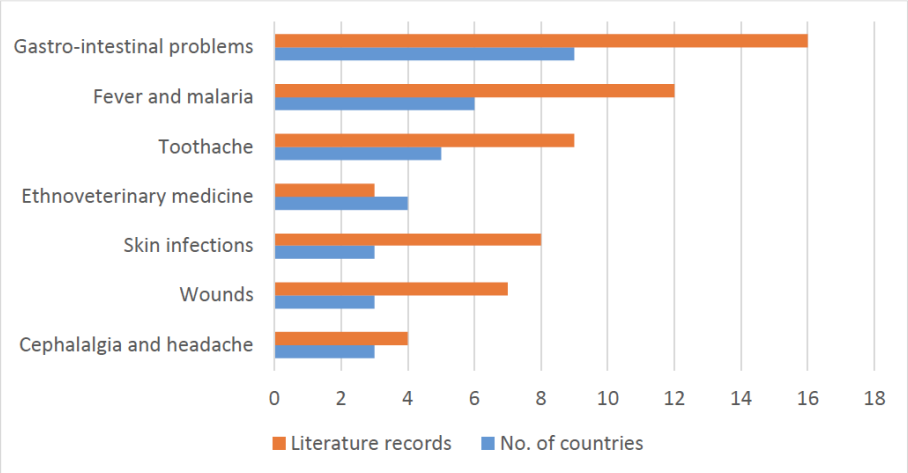

Figure 1: Medicinal applications of *Maerua crassifolia* derived from literature records.

M. crassifolia is mixed with fruits of *Capsicum annuum* L. and *Cuminum cyminum* L. as traditional medicines for abdominal pain, appetite loss, fever and malaria [37]. Diallo *et al.* [37] also argued that the leaves of *M. crassifolia* are mixed with those of *Hibiscus sabdariffa* L. as herbal medicine for malaria. In Mauritania, the leaves of *M. crassifolia* are mixed with the gum of *Senegalia senegal* (L.) Britton as traditional medicine for diabetes [38]. In Oman, a paste made from the powdered leaves of *M. crassifolia* and those of *Lawsonia inermis* L., which is placed on the fractured bone to reduce pain [39-42].

Nutritional and Phytochemistry

Some researchers identified nutritional elements and phytochemical compounds from the aerial parts and leaves of *M. crassifolia* and these include alkaloids, amino acids, betaines, fatty acids, flavonoids, lignan glucosides, phenolics, tannins, nutritional compounds, quaternary ammonium compounds, minor and major elements (Table **2**). Other phytochemical compounds identified from the leaves of *M. crassifolia* include cardiac glycosides, phenols, resins, saponins, steroids and terpenoids [59-61].

Pharmacological Properties

The following pharmacological activities have been documented from the aerial parts, leaves and stems of *M. crassifolia*: antibacterial, anti-diarrhoeal, analgesic, anti-inflammatory, antioxidant, antiplasmodial, antiprotozoal, antitrypanosomal, antipyretic and cytotoxicity activities.

Antibacterial Activities

Abdel-Sattar *et al*. [69] evaluated the antibacterial activities of the methanol extract of M. crassifolia aerial parts against Escherichia coli, Proteus vulgaris, Pseudomonas aeruginosa, Staphylococcus aureus, Sarcina lutea, Bacillus subtilis and Mycobacterium phlei using agar-diffusion method with ofoxacine (5.0 µg/disc) as positive control. The extract exhibited activities against all tested pathogens with the exception of Mycobacterium phlei, with zone of inhibition ranging from 10.0 mm to 15.0 mm [69]. Ckilaka et al. [60] evaluated the antibacterial activities of the methanol leaf extract of M. crassifolia against Staphylococcus aureus, Shigella spp., Salmonella typhi, Bacillus subtilis and Escherichia coli using disc diffusion and broth micro dilution methods. The extract exhibited activities against the tested pathogens with the zone of inhibition ranging from 7.8 mm to 29.6 mm while the minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC) values ranged from 7.0 µg/ml to 24.0 µg/ml [60].

Anti-Diarrhoeal Activities

Akuodor *et al.* [59] evaluated the anti-diarrhoeal activities of the methanol extract of *M. crassifolia* leaves in Wistar albino rats. The extract decreased intestinal propulsion of charcoal meal in rats in a dose-dependent manner and the extract produced 100% inhibition of castor oil-induced diarrhoea [59].

Analgesic Activities

Akuodor *et al.* [61] evaluated the analgesic activities of the methanol leaf extract of *M. crassifolia* in Albino mice using the acetic acid-induced writhing and tail immersion methods. The extract at doses of 100.0, 200.0 and 400.0 mg/kg exhibited dose-dependent inhibition of pain in acetic acid-induced writhing and tail immersion tests [61].

Table 2: Nutritional and Phytochemical Composition of *Maerua crassifolia*

Nutritional and chemical compound	Value	Plant part	Reference
Nutritional components			
Acid detergent fibre (%)	17.0	Leaves	[29]
Acid detergent lignin (%)	3.5	Leaves	[29]
Aluminium (µg/g)	140.0	Leaves	[17]
Ash (g/100g)	12.2 – 13.2	Leaves	[15,62]
Cadmium (µg/g)	0.05	Leaves	[62]
Calcium (µg/g)	17000.0 - 24000.0	Leaves	[17,18]
Carbohydrate (g/100g)	54.2 – 64.8	Leaves	[15,62]
Chromium (µg/g)	1.5 – 5.2	Leaves	[17,18]
Copper (µg/g)	0.2 – 3.9	Leaves	[17,18,62]
Crude fibre (g/100g)	4.7	Leaves	[62]
Crude lipids (g/100g)	3.2	Leaves	[62]
Protein (g/100g)	15.2 – 28.0	Leaves	[15,62]
Dry matter (g/100g)	97.5	Leaves	[15]
Fat (g/100g)	4.1	Leaves	[15,18]
Gross energy (kcal)	358.0	Leaves	[15]
Iron (µg/g)	180.0 – 499.0	Leaves	[17,18]
Magnesium (µg/g)	5710.0 - 7290	Leaves	[17,18]
Manganese (µg/g)	29.9 – 110.0	Leaves	[17,18]
Moisture (%)	62.0	Leaves	[62]
Molybdenum (µg/g)	5.1 – 22.3	Leaves	[17,18]
Neutral detergent fibre (%)	23.1	Leaves	[29]
Nickel (µg/g)	5.0	Leaves	[18]
Phosphorus (µg/g)	1430.0	Leaves	[18]
Potassium (µg/g)	35700.0	Leaves	[18]
Selenium (µg/g)	0.2 – 33.9	Leaves	[17,18,62]
Sodium (µg/g)	1070.0	Leaves	[18]
Zinc (µg/g)	8.3	Leaves	[17,18,62]
Anti-nutritional components			
Cyanide (mg/100g)	0.2	Leaves	[62]
Oxalate (mg/100g)	0.01	Leaves	[62]
Phytate (mg/100g)	2.3	Leaves	[62]
Amino acids			
Alanine (mg/g)	8.9 – 23.4	Leaves	[17,18]
Arginine (mg/g)	9.5 – 23.9	Leaves	[17,18]
Aspartic acid (mg/g)	11.4 - 31.3	Leaves	[17,18]
Cysteine (mg/g)	3.6 – 6.8	Leaves	[17,18]
Glutamic acid (mg/g)	16.6 - 41.5	Leaves	[17,18]
Glycine (mg/g)	8.0 – 19.5	Leaves	[17,18]
Histidine (mg/g)	9.9 – 154.0	Leaves	[15,17,18]
Isoleucine (mg/g)	7.5 – 303.0	Leaves	[15,17,18]
Leucine (mg/g)	13.8 – 545.0	Leaves	[15,17,18]
Lysine (mg/g)	8.6 – 420.0	Leaves	[15,17,18]
Methionine (mg/g)	2.0 – 5.1	Leaves	[17,18]
Phenylalanine (mg/g)	10.3 – 28.2	Leaves	[17,18]
Proline (mg/g)	9.8 – 23.9	Leaves	[17,18]
Serine (mg/g)	7.1 – 19.5	Leaves	[17,18]
Threonine (mg/g)	5.8 – 324.0	Leaves	[15,17,18]
Tyrosine (mg/g)	9.3 – 23.3	Leaves	[17,18]
Tryptophan (mg/g)	8.6 – 176.0	Leaves	[15,17,18]
Valine (mg/g)	9.9 – 373.0	Leaves	[15,17,18]

(Table 2). Continued.

Nutritional and chemical compound	Value	Plant part	Reference
Fatty acids			
Hexadecanoic acid (mg/g)	2.9 - 3.2	Leaves	[17,18]
Stearic acid (mg/g)	0.9 - 1.1	Leaves	[17,18]
Oleic acid (mg/g)	1.0	Leaves	[17,18]
Linoleic acid (mg/g)	1.0 – 1.3	Leaves	[17,18]
α-linolenic acid (mg/g)	4.4 – 9.3	Leaves	[17,18]
Betaines			
3-hydroxyprolinebetaine	-	Leaves	[63]
Glycinebetaine	-	Leaves	[63]
Prolinebetaine	-	Leaves	[63]
Flavonoids			
Flavonoids (mg catechin/g of extract)	15.7	Leaves	[25]
Kaempferol	-	Aerial parts	[43]
Kaempferol-3-O-galactorhamnoside	-	Aerial parts	[43]
Quercetin	-	Aerial parts	[43]
Quercetin-3-O-arabinopyranoside	-	Aerial parts	[43]
Rutin	-	Aerial parts	[43]
Glucosides			
Ionol glucoside	-	Aerial parts	[64,65]
Iyoniresincl-3-O-glucopyranoside	-	Aerial parts	[43]
3-O-β-D-galactopyranoside	-	Aerial parts	[64]
6-N-methyl-9-β-D-glucoside adenine	-	Aerial parts	[66]
3,4,5-trimethoxyphenol-1-O-β-D-glucopyranoside	-	Aerial parts	[66]
Guaiacyl glycerol	-	Aerial parts	[66]
Lipids and triterpenes			
1,23 dimethoxy tricosa-6-one	-	Aerial parts	[67]
Triacontane	-	Aerial parts	[67]
Ceryl alcohol	-	Aerial parts	[67]
Lupeol palmitate	-	Aerial parts	[67]
β-sitosterol palmitate	-	Aerial parts	[67]
Lupeol acetate	-	Aerial parts	[67]
α-amyrin	-	Aerial parts	[67]
Other compounds			
3-hydroxy-1,1-dimethyl prrolidinium	-	Leaves	[63]
Stachydrine	-	Aerial parts	[43]
Polyphenol (mg gallic acid/g of extract)	35.1	Leaves	[25]
Tannins (mg catechin/g of extract)	10.2	Leaves	[25]
Trypsin inhibitor (μg/mg dry weight)	3.8 – 8.2	Leaves	[68]

Anti-Inflammatory Activities

Akuodor *et al.* [61] evaluated the anti-inflammatory activities of the methanol leaf extract of *M. crassifolia* in Albino mice and rats using the xylene and carrageenan-induced paw oedema methods with aspirin (150.0 mg/kg) and dexamethasone (4.0 mg/kg) as positive controls. The extract reduced the xylene-induced ear oedema in mice and the activities exhibited by the extract were comparable to those exhibited by the positive control. On carrageenan-induced paw oedema, the extract exhibited dose-dependent activities and these activities were comparable to those exhibited by the positive control [61].

Antioxidant Activities

Chaib *et al.* [25] evaluated the antioxidant activities of the methanol leaf extract of *M. crassifolia* using the

2,2-diphenyl-1-picrylhydrazyl (DPPH) free radical scavenging assay with ascorbic acid as positive control. The extract exhibited weak activities with half maximal inhibitory concentration (IC_{50}) value of 122.9 µg/ml [25]. Ckilaka *et al.* [60] evaluated the antioxidant activities of the methanol leaf extract of *M. crassifolia* using the DPPH free radical scavenging assay with ascorbic acid as positive control. The extract exhibited activities with the IC_{50} value of 58.9 µg/ml in comparison to the IC_{50} value of 4.8 µg/ml exhibited by the positive control [60].

Antiplasmodial Activities

Abdel-Sattar *et al.* [71] evaluated the antiplasmodial activities of methanol extracts of *M. crassifolia* stems against *Plasmodium falciparum*$_{GHA}$-strain using the parasite lactate deshydrogenase as an assay with chloroquine as positive control. The extract exhibited weak activities with the IC_{50} value of 43.9 µg/ml [71]. Akuodor *et al.* [70] evaluated the *in vivo* antiplasmodial activities of methanol leaf extract of *M. crassifolia* in mice infected with chloroquine sensitive *Plasmodium berghei berghei* at dose levels of 100.0, 200.0 and 400.0 mg/kg p.o. with chloroquine (10.0 mg/kg) as the standard drug. The extract exhibited dose-dependent chemo-suppression of the tested parasite of 71.0%, 80.0% and 86.0% at doses of 100.0, 200.0 and 400.0 mg/kg, respectively, in comparison to 93.0% exhibited by the positive control [70].

Antiprotozoal Activities

Camacho *et al.* [47] evaluated the antiprotozoal activities of methanol and aqueous extracts of *M. crassifolia* stems against *Leishmania donovani* using the antileishmanial assay with the antileishmanial drug pentamidine used as positive control. The methanol and aqueous extracts exhibited weak activities with the IC_{50} values of 371.5 µg/ml and >500.0 µg/ml, respectively [47]. Abdel-Sattar *et al.* [71] evaluated the antiprotozoal activities of methanol and aqueous extracts of *M. crassifolia* stems against *Leishmania infantum* amastigotes using an *in vitro* antileishmanial assay with miltefosin as a positive control. The extract exhibited weak activities against the tested pathogen with the IC_{50} value >64.0 µg/ml [71].

Antitrypanosomal Activities

Abdel-Sattar *et al.* [71] evaluated the antitrypanosomal activities of methanol extracts of *M. crassifolia* stems against the trypomastigotes of *Trypanosoma brucei brucei* squib-427 strain and *Trypanosoma cruzi* using the Alamar Blue and an enzyme-linked immunosorbent assay with benznidazole and suramin as positive controls. The extract exhibited weak activities against *Trypanosoma brucei brucei* and *Trypanosoma cruzi* with the IC_{50} values of 33.5 µg/ml and 29.8 µg/ml, respectively [71].

Antipyretic Activities

Akuodor *et al.* [61] evaluated the antipyretic activities of the methanol leaf extract of *M. crassifolia* in Albino rats using the yeast and amphetamine-induced pyrexia method. The extract exhibited activities by causing a reduction in hyperpyrexia [61].

Cytotoxicity Activities

Camacho *et al.* [47] evaluated the cytotoxicity activities of methanol and aqueous extracts of *M. crassifolia* stems using a micro dilution technique against KB cells. The aqueous and methanol extracts exhibited weak activities with IC_{50} values of 172.8 µg/ml and >500.0 µg/ml, respectively [47]. Abdel-Sattar *et al.* [71] evaluated the cytotoxicity activities of methanol extracts of *M. crassifolia* stems against MRC-5 cell lines using the colony assay with vinblastine as positive control. The extract exhibited weak activities with half maximal cytotoxicity concentration (CC_{50}) value of >64.0 µg/ml [71].

CONCLUSION

Research on *M. crassifolia* over the past decades shown that this species is an important food plant in the dry Sahel region and other countries in the savanna biome. The species is currently collected from the wild and previous research showed that *M. crassifolia* has great promise as a source of food, fodder and herbal medicines. Therefore, future research should also focus on evaluating phytochemical, pharmacological and toxicological evaluations of the crude extracts and compounds isolated from the species, aimed at correlating its medicinal uses with its phytochemistry and pharmacological activities.

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