Abstract

Ochna schweinfurthiana (Os, Family: Ochnaceae) is a small evergreen tree used in ethnomedicine to treat different ailments; it is also used in agri-horticulture and as ornaments, dyes among others. Chemical investigations conducted on the different parts of the plant have been confined to phenolic compounds majorly bioflavonoids, glycosides, steroids and terpenes. The plant, Os have shown a wide spectrum of biological and pharmacological properties which include antimicrobial, cytotoxic/antiproliferative, genotoxicity, anticinociceptive, anti-inflammatory, antioxidant and antiplasmodial. This review comprehensively summarize the potential effects of the plant Os chemically and pharmacologically (in vitro and in vivo). However, more researches in the aspect of phytochemical and biological studies are needed to exhaustively isolate bioactive compounds and evaluate their effects on other ailments as claimed by the traditional healers.

Keywords: Ochnaceae, antimicrobial, antiproliferative, anti-inflammatory, antiplasmodial, bioflavonoids, glycosides, steroids, toxicity

1. Introduction

Ochna schweinfurthiana (Os) belonging to the Ochnaceae family is a small tree that was named after a German botanical collector and taxonomist Dr. Georg August Schweinfurth; it is an attractive tropical small tree that measures up to 4 m tall and the plant is commonly known as the brick-red Ochna in English, Jan-taru in Hausa language, Hiéké in Yoruba and Sa’aboule in Foufoudé (Burkill, 1985; Messi et al., 2016). The plant can be used as medicine, for agricultural, social and religious purposes (Burkill, 1985). This review will focus on the phytochemical and pharmacological properties of Os.

2. Main text

2.1 Botanical Description

Ochna originated from a Greek word “Ochne” which means wild pear”. It was named by Linnaeus in 1951 as Ochna because of the resemblance of their leaves with those of wild pear (Muema, 2015). It is an old world genus of mainly trees, shrubs and shrublets which comprises of about 85 species (Verdcourt, 2005) and it is widely distributed widely in tropical Asia, Africa and America (Rendle, 1952) of which eleven (11) species occur in India (Kirtikar, 2012). Ochna’s are usually called Mickey Mouse plants, as a result of the appearance of their black druplets fruits sitting. The Ochnaceae family is mainly comprised of trees and shrubs with about 33 genera and 550 species (Christenhusz and Byng, 2016) which are highly distributed around the globe; the species are mostly found in Tropical Africa, Asia, Australia, Madagascar, the Mascarene island and America (Mabberley, 2008). They are notably known for their unusual leaves that are shiny, with closely spaced, parallel veins, toothed margins, and conspicuous stipules (Burkill, 1985; Christenhusz and Byng, 2016). The largest genera are Ouratea, Ochna, Campylospermum, Sauvagesia and Quinia with 200, 85, 65, 39 and 34 species respectively (Table 1).
Table 1: Ochnaceae subfamilies and their estimated number of species

| Subfamily          | Estimated number of species |
|--------------------|-----------------------------|
| Ouratea            | 200                         |
| Ochna              | 85                          |
| Campylospermum     | 65                          |
| Sauvagesia         | 39                          |
| Quiina             | 34                          |
| **Total**          | **423**                     |

Source: (Simpson, 1979)

2.2 Morphology

*O. schweinfurthiana* is a shrub or small evergreen tree that grows up to 4 m tall and has a dark grey bark that is fissured and cracked, separating into square segments (Hyde *et al.*, 2019). The leaves are olive-green (1-13.5 x 1.7-5.5 cm) that oblanceolate to oblong or elliptic, apex somewhat rounded, base tapers into the petiole, margins rather bluntly toothed (serrulate), sometimes appearing almost scalloped, net-veining conspicuous on the upper surface and young leaves are coppery (Burkill, 1985; Anonymous, 2019). It bears bright yellow flowers (1.5 cm diameter) which are sweetly-scented from September to November, very short-lived, normally appearing before or with the young leaves (Hyde *et al.*, 2019). In addition, it appeared in a condensed raceme with 4 – 10 flowers on a short central stem and the petals fall very early (Anonymous, 2019). The fruits of *O. are 1-5 ovalappearing between August and January, attached at the base are 2 – 4 black berries when ripe; they are enlarged, borne on brick-red persistent sepalts turning cherry to brick-red. The bark is dark grey, thick, and deeply fissured into a grid-like pattern (Anonymous, 2019; Hyde *et al.*, 2019).

2.3 Taxonomy

**Kingdom**: Plantae  
**Order**: Malpighiales  
**Family**: Ochnaceae  
**Subfamily**: Ochnoideae  
**Genus**: Ochna  
**Species**: *O. schweinfurthiana* (Simpson, 1979)

2.4 Common names

**English**: Brick-red Ochna  
**Hausa**: Jan-taru  
**Yoruba**: Hiéké  
**Foufouldé**: Sa’aboule

2.5 Habitat, Distribution and Ecology

The plant grows in open deciduous woodland in tropical regions in Africa from Guinea to northern and Southern Nigeria and across central Africa to Sudan, Uganda, Zimbabwe, Mozambique, Tanzania and Angola. It has medium water requirement when young and grows fast, flowers from September to November. It required low maintenance and attracts insects and birds (Verdcourt 2005; Hyde *et al.*, 2019).
2.6 Picture of *O. schweinfurthiana*

Figure 1 & 2: Leaf and fruits of *O. schweinfurthiana* (Photograph by GleniceEbedes)

Figure 3 & 4: Branch with fruits and whole plant of *O. schweinfurthiana* (Photograph by GleniceEbedes)

3. Uses

3.1 Ethnomedicinal uses

Several preparations (powdered and decoction) of the leaves and/or root of the *Os* have found a general use as an antimicrobial (wound dressing, eye infection), analgesic, anti-inflammatory and anthelmintic agents (Burkill, 1985). The leaf is also used as a laxative, enema, febrifuge, antiseptic, stimulant, among others (Burkill, 1985). In Northern Cameroon, *Os* is used to treat...
different metabolic diseases such as rubella, burns, stomachache and multiple sclerosis (Abdullahi et al., 2010); the root of the plant is also used to treat headache, stomach and eye aches while the leaves are used in the treatment of toothaches (Messiet al., 2016).

The powdered bark is used as antimalarial, febrifuges and anthelmintic, while the decoction of the root, leaves or bark is used in dressing wounds (Abdullahi et al., 2010). In Northern Nigeria, the plant is used for the treatment of measles, typhoid fever and fungal skin infections (Abdullahi et al., 2010). The macerated roots of Os have been reportedly used to induce/speed the delivery process and for miscarriage (Bruschiet al., 2011).

3.2 Other uses
The plant is used in agri-horticulture; the bark and flowers Os are cultivated for ornaments, dyes, stains, inks, tattoos and mordant among others. The wood is used for farming, forestry, hunting and fishing apparatus. The leaf has social, religious, superstitious and magic values among others (Burkill, 1985).

4. Phytochemistry
4.1 Phytochemical screening
Abdullahi et al.(2010) reported the presence of flavonoids, steroids/terpenes and saponins in the acetone leaf extract of Os and the methanol leaf extract indicated the presence of flavonoids and saponins. However, flavonoids, saponins, glycosides, tannins and steroids/terpenes were reported on the methanol stem extract of Os (Danmusa et al., 2015). A study conducted by Ibrahim et al. (2015) reported the presence of carbohydrates, steroids/terpenes, glycosides, saponins, tannins and flavonoids in the methanol leaf extract of Os.

4.2 Bioactive constituents
The main bioactive constituents isolated from Os fall under the following class of secondary metabolites; phenolic – flavonoids, glycosides and sugars.

Os have been reported to contain phenolic derivatives (such as flavonoids, bioflavonoids) which appear as free or in polymerized forms. Isolation and characterization of quercetin-3-O-β-D-glucopyranosyl-(1→6)-α-rhamnoside (1) (quercetin rutinoside) from the n-butanol soluble fraction of methanol leaf extract of Os was reported (Abdullahi et al., 2011). A novel compound, tri-methoxy lophirone (2) was isolated from the chloroform soluble fraction of the methanol root extract of Os (Abdullahi et al., 2014).

Ndongo et al. (2015) reported the isolation of seven flavonoids, hemerocallone (3), 6,7-dimethoxy-3′,4′-dimethoxyisoflavone (4), amentoflavone (5), agathisflavone (6), cupressusflavone (7), robustaflavone (8), and epicatechin (9), and three other compounds including, lithospermoside (10), β-D-fructofuranosyl-α-D-glucopyranoside (11) and 3β-O-D-glucopyranosyl-β-stigmasterol (12) from the ethyl acetate extract of the stem bark of Os.

The roots of Os were reported to contain three new compounds viz; 4″-methoxyliphilon A (13), 4,4″,4‴-trimethoxyliphoron A (14) and (4E,7Z)-3,8-dicarboxy-1-(O-β-D-glucopyranosyl-(1→6))-O-β-D-glucopyranosyl-2,9-dihydroxyhexeicosa-4,7-diene (15). Six known compounds were also identified, including calodenone (16), calodenine B (17), lophirone A (18), gerontosiflavone A (19), 16α,17-dihydroxy-ent-kauran-19-oic acid (20) and 3β-O-D-glucopyranosyl-β-sitosterol (21) (Messiet al., 2016).

Six known compounds were isolated from the powdered bark of Os and they include, hemerocallone (3), 6,7-dimethoxy-3′,4′-dimethoxyisoflavone (4), lithospermoside (10), amentoflavone (5), agathisflavone (6) and β-D-fructofuranosyl-α-D-glucopyranoside (11) (Djova et al., 2019).
Comment [D23]: Write name of each constituent just below the image.

Reviewer's Comments
5 Biological and Pharmacological activities
5.1 Antimicrobial activity
The acetone and methanol leaf extracts of Os had a remarkable antibacterial effect against S. aureus, S. typhi, K. pneumonia and P. aeruginosa with a mean zone of inhibition range of 15 – 21 mm; the extracts had an MIC and MBC values of 10 – 20 mg/mL and 20 – 40 mg/mL, respectively (Abdullahi et al., 2010).

Quercetin-3-O-β-D-glucopyranosyl(1→6)-α-rhamnoside(1) from the n-butanol soluble fraction of methanolic leaf extract of Os showed an in vitro inhibitory effect against some bacterial isolates such as S. aureus, MRSA, S. pyogenes, E. coli, K. pneumonia, S. typhi and P. aeruginosa with an MIC and MBC range between 2.5 – 5.0 and 5 – 20 µg/mL, but there was no effect against B. subtilis, C. ulcerans and C. albicans (Abdullahi et al., 2011).

Earlier studies showed that tri-methoxy lophirone A (2) from the chloroform soluble fraction of the methanol root extract of Os inhibited the growth of some selected human pathogens including S. aureus, S. pyogenes, P. aeruginosa, K. pneumonia and S. typhi with an MIC and MFC values of 5 µg/mL and 20 µg/mL (Abdullahi et al., 2014).

Crude methanol stem extract of Os and its chloroform (CF), ethylacetate (EF) and n-butanol (BF) fractions inhibited the growth of MRSA, S. aureus, S. pyogenes, S. typhi, S. dysenteriae, K.
The methanol and ethylacetate stem bark extracts of Os demonstrated cytotoxicity against HeLa cells; mentoflavone (5) and agathisflavone (6) were also active (Ndongo et al., 2015). Antiproliferative effect of Os extract was evaluated against Glioblastoma multiforme (GBM U-1242 MG) cell line and the extract reduce cell count by 20 % with an IC_{50} value 823.51 µg/mL (Abdullahi et al., 2016).

The aqueous stem bark of Os did not show any cytotoxic effect on Vero monkey kidney cell line after 48 h incubation with an LC_{50} value 50±1 µg/mL (Djova et al., 2019).

5.3 Genotoxicity
Djova et al. (2019) reported that the extracts of Os were nongenotoxic in a study he carried out; this is because none of the plant extracts demonstrated a dose dependent increase or revertent colonies ≥ the number of negative control revertent colonies; thus, the plant Os is devoid of any genotoxic substances that can lead to mutations either by substitution or by reversion in the genetic material.

5.4 Antinoceptive and Anti-inflammatory effect
The methanol leaf extract of Os significantly inhibited the writhing response induced by acetic acid in a dose dependent manner; the highest dose exhibited maximum inhibition of pain (84.3 %). In addition, the extract was also able to attenuate pain response in a similar manner though with a slower onset of action in the tail flick model (Ibrahim et al., 2015a).

The aqueous stem bark of Os exhibited good anti-inflammatory effect in both ferrous oxidation-Xylenol Orange (Fox) and BSA denaturation assays; the extract demonstrated good 15-lipoxygenase inhibitory effect with an IC_{50} value of 32.2±0.36µg/mL, however, an IC_{50} of 130±5.78µg/mL was recorded by the extract in the inhibition of heat induced albumin denaturation (Djova et al., 2019).

5.5 Antioxidant effect
Messiet al. (2016) evaluated the antioxidant activity of some compounds including 4”- methoxylophirone (13), calodenone (16), calodenine B (17), lophirone A (18), gerontoisoflavone A (19) from the roots of Os using DPPH radical scavenging and ferric reducing-antioxidant power (FRAP) assays. In the DPPH radical scavenging, calodenine B (17) showed prominent effect with SC_{50} = 0.17±0.04 µM and EC_{50} = 4.25 µM, gerontoisoflavone A (19) exhibited weak activity in all the models applied with SC_{50} = 19.00 µM and SC_{50} = 78.67 µg EAA/mg/dw in DPPH and FRAP respectively.

The antioxidant property of the leaf, stem bark and fraction of Os was conducted (Nyegue et al., 2016).

5.6 Antiplasmodial effect
An in vivo study showed that the methanol leaf extract of Os exerted a suppressive effect against Plasmodium berghei at a lower dose (50 mg/kg); Ibrahim et al. (2015b) concluded that, the ability of the extract to suppress malaria at the early stage is an indication that, it possess blood schizontocidal activity. Moreso, the extract reduced the level of parasitaemia with 100 % cure at the lowest dose (50 mg/kg); the percentage inhibition of parasitaemia was higher than the chemo suppression due to non-selectivity of the extract to the proliferative process of the parasite (Salawuet al., 2010; Ibrahim et al., 2015b).
Antiplasmodial effect of the ethylacetate roots extract of Os and some compounds 4”-methoxylophirone A (13), (4E,7Z)-3,8-dicarboxy-1-(O-β-D-glucopyranosyl-(1→6)-O-β-D-glucopyranosyl-2,9-dihydroxyhexecosa-4,7-diene (15), calodeline B (17), lophirone A (18) and gerontosiflavanone A (19) were investigated in vitro; 4”-methoxylophirone A (13) showed good antiplasmodial effect against Plasmodium falciparum strain 3D7; this effect as explained by Messier et al. (2016) might be related to the presence of a methoxy group on position C-4” which has been known to enhance lipophilicity thereby enhancing its movement into the cells (Monks et al., 2002); other compounds were inactive (Messier et al., 2016).

Cold and hot aqueous leaf extracts of Os possess inhibitory effect against P. falciparum in vitro; thus there was significant reduction of parasitaemia. The high dose (80 µg/mL) exhibited 86.42 % (cold extract) and 85.06 % (hot extract) reduction of parasitaemia. On the other hand, no any significant difference was observed on the plasmodium lactate dehydrogenase (LDH) activity of the treated extract when compared with the standard drug (Omoniwa, 2017).

5.7 Toxicity
Toxicity level of Os was assessed in mice both orally and intraperitoneally. The methanol leaf extract of the plant produced an LD50 774.6 mg/kg, i. p. while the oral LD50 value for the extract was 5000 mg/kg; according to this study, the plant is toxic intraperitoneally and safe orally (Ibrahim et al., 2015b).

Conclusion
Os exhibit a variety of biological effects; the plant is considered to be effective against cancer, malaria, oxidative stress, pain, inflammation and a wide range of microbes; thus, the pharmacological actions have been attributed to the presence of different classes of secondary metabolites such as biflavonoids, glycosides, steroids and terpenes among other. In addition, the mechanism of action of the observed effects and evaluation of other pharmacological properties of Os still need attention and it should be the objective of new researches on Os.

References
Abdullahi, M.I, Musa, A.M., Haruna, A.K., Sule, M.I., Abdulmalik, M., Abdullahi, S.M., Abimiku, A.G., Iliya I. (2014). Isolation and characterization of anti-microbial biflavonoid from the chloroform-soluble fraction of methanol root extract of Ochna schweinfurthiana (Ochnaceae). African Journal of Pharmacy and Pharmacology, 8(4): 93 – 99. DOI: 10.5897/AJPP2013.3520. http://www.academicjournals.org/ajpp.

Abdullahi, M.I, Musa, A.M., Haruna, A.K., Sule, M.I., Abdullahi, S.M., Abdulmalik, M., Akinwande, Y., Abimiku, A.G., Iliya I. (2011). Anti-microbial flavonoid diglycoside from the leaf of Ochna schweinfurthiana Hoffm. (Ochnaceae). Nigerian Journal of Pharmaceutical Sciences, 10(2): 1 – 7.

Abdullahi, M.I, Musa, A.M., Tajuddeen, N., Mohammed, G.M., Yusuf, A.J., Iliya I. (2016). Anti-proliferative study and isolation of Ochnaflavone from the ethylacetate-soluble fraction of Ochna kibbiensis Hutch &Dalziel. Natural Product Research, DOI:10.1080/14786419.2016.1274892.

Abdullahi, M.I., Iliya, I., Haruna A.K., Sule, M.I., Musa, A.M., Abdullahi, S.M. (2010). Preliminary phytochemical and antimicrobial investigations of leaf extracts of Ochna schweinfurthiana. African Journal of Pharmacy and Pharmacology, 4(2): 083 -086. Available online at http://www.academicjournals.org/ajpp.

Anonymous (2019). Ochna schweinfurthiana: PLANT BOOK. Available online at www.plantbook.co.za/occhna-schweinfurthiana retrieved 28 September, 2019

Bruschi, P., Morganti, M., Mancini, M., Signorini, M.A. (2011). Traditional healers and laypeople: A qualitative and quantitative approach to local knowledge on medicinal plants in Muda (Mozambique). Journal of Ethnopharmacology, 138: 543 – 563.
Burkill, M.H. (1985). The Useful Plants of West Tropical Africa, Families J–L, vol. 4. Royal Botanic Gardens Kew, pp. 4: 275.

Christenhusz, M. J. M., Byng, J. W (2016). The number of known plants species in the world and its annual increase. *Phytotextarea*. 261(3): 201–217.

Dannusa, U.M., Nasir, I.A., Abdullahi, M.I., Ahmad, A.A., Abdulkadir, I.S. (2015). Phytochemical analysis and antimicrobial activities of methanolic stem extracts of *Ochna schweinfurthiana* F. Hoffm. *Journal of Pharmacy and Pharmacognosy*. 3(6): 171 – 182. Available online at http://jppres.com/jppres.

Djova, S.V., Nyegue, M.A., Messi, A.N., Afagnigni, A.D., Etoa, F-X. (2019). Phytochemical study of aqueous extract of *Ochna schweinfurthiana* F. Hoffm powder bark and evaluation of their anti-inflammatory, cytotoxic and genotoxic properties. *Hindawi Evidence-Based Complementary and Alternative Medicine*. https://doi.org/10.1155/2019/8908343.

Hyde, M.A., Wursten, B.T., Ballings, P., Coates, P.M. (2019). Flora of Zimbabwe: Species information: *Ochna schweinfurthiana* F. Hoffm. Available online at www.zimbabweflora.co.zw/speciesdata/species.php?species_id=140320, retrieved 28 September, 2019.

Ibrahim, Z.Y.Y., Abdullahi, M.I., Musa, A.M., Maje, I.M., Yusuf, A.J, Aliyu, I.M. (2015b). Acute toxicity profile and *Plasmodium berghei* inhibitory activity of *Ochna schweinfurthiana* (F. Hoffm) Ochnaceae leaf extract in Laboratory animals. *International Journal of Pharmacy Sciences and Research*. 6(10): 1302 – 1306.

Ibrahim, Z.Y.Y., Musa, A.M., Abdullahi, M.I., Uba, A., Yusuf, A.J, Aliyu, I.M., Ya’u, J. (2015a). Phytochemical and antinociceptive studies on the *Ochna schweinfurthiana* (Ochnaceae). *International Journal of Advances in Pharmacy, Biology and Chemistry*. 4(4): 838 – 843.

Kirtikar, K. R. and Bussu, B. D. (2012). Indian medicinal plants, vol. 2, periodical expert book agency, Delhi. Pp. 1539.

Mabberley, D. J. (2008). Mabberley’s plant-book. A portable dictionary of plants, their classification and uses. Cambridge university press, Cambridge. Pp 342.

Messa, A.N., Mbing, J.N., Ndongo, J.T., Nyegue, M.A., Tchinda, A.T., Yemeda, M.F., Pegnyemb, D.E. (2016). Phenolic compounds from the roots of *Ochna schweinfurthiana* and their antioxidant and antiplasmodial activities. *Phytochemistry Letters*. 17: 119 – 125. Available online at http://dx.doi.org/10.1016/j.phytol.2016.07.011.

Monks, M.R., Ferraz, A., Bordignon, S.A., Machado, K.R., Richter, M.F., da Rocha, A.B. (2002). In vitro cytotoxicity of extracts from Brazilian Asteraceae. *Pharm. Biol*. 40, 494–500.

Muema, M. J. (2015). Phytochemical and antimicrobial investigation of *Ochna thomasiensis*Engl. and Gilg. MSc Thesis, Department of Chemistry, Kenya University. Pp. 30 – 35.

Ndongo, J.T., Issa, M.E., Messi, A.N., Ngo Mbing, J., Cuendet, M., Pegnyemb, D.E., Bochet, C.G. (2015). Cytotoxic flavonoids and other constituents from the stem bark of *Ochna schweinfurthiana*. *Natural Product Research*. 17, 1684–1687.

Nyegue, M.A., Ngo Mbing, J., Djova, S.V. et al. (2016). Evaluation of the antioxidant activity of the leaves, stem-barks extracts and fractions of *Ochna schweinfurthiana* F. Hoffm (Ochnaceae). *African Journal of Pharmacy and Pharmacology*. 10(17): 370–378.

Omoniwa, B.P. (2017). *In-vitro* antiplasmodial activity of cold and hot aqueous extracts of *Ochna schweinfurthiana* leaf. *Journal of Bacteriol/Parasitol*. 8(Suppl): pp 30.

Rendle, A. B. (1952). The classification of flowering plants. Vol 2, Cambridge University Press, London. Pp 12-18.

Salawu, O.A., Tijani, A.Y., Babayi, H., Nwaeeze, A.C., Anagbogu, R.A., Agbakwuru, V.A. (2010). Anti-malarial activity of ethanolic stem bark extract of *Faidherbia albida* (Del) a. Chev. (Mimosoideae) in mice. *Afr App Sci Res*. 2: 261-268.

Simpson, D.P. (1979). Cassell's Latin Dictionary (5 ed.). London: Cassell Ltd. p. 883. ISBN 0-304-52257-0.

Verdecourt, B. (2005). Ochnaceae. Flora of Tropical East Africa. Royal Botanic Gardens, Kew, Richmond, United Kingdom. Pp 60.