

Variable drug bio availability of native seaweeds in India for antimalarial therapeutics

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ABSTRACT

A most important feature for the success of any planned reaction is the selection of a suitable solvent: solvents influence both chemical reactivity and reaction rates. The term “solvent polarity” lacks an exact definition, but it is generally used to encompass all of the intermolecular interactions of which the solvent is capable. Polar solvents have large dipole moments; they contain bonds between atoms with very different electronegativities, such as oxygen and hydrogen, polar reactants will dissolve in polar solvents and non-polar solvents dissolve non-polar compounds best. The present investigation was carried out to find out the antiplasmodial potential of crude seaweed extracts with three different polar solvents. Among the seaweed extracts tested, the crude extracts of *Sargassum wightii* and *Valoniopsis pachynema* exhibited excellent antiplasmodial activity of $IC_{50} < 3.125 \mu\text{g. ml}^{-1}$ in all the three solvents (Petroleum ether, Ethyl acetate and ethyl alcohol) used at 48 h of incubation. This activity is highly comparable to the activity of positive control artemether ($IC_{50} < 3.125 \mu\text{g. ml}^{-1}$). Statistical analysis reveals that, the significant *in vitro* antiplasmodial activity ($P < 0.05$) was observed between the concentration and time of exposure. The chemical injury to erythrocytes was done and it shows no morphological changes in erythrocytes by all the three solvent extracts. The results revealed that, the crude seaweed extract of *S.wightii* and *V. pachynema* collected from South West coast of India possess variable drug bioavailability for the development of antiplasmodial agents.

Keywords: antimalarial drug, antiplasmodial activity, drug bioavailability, *Plasmodium falciparum*, Seaweed extracts, Solvent polarity.

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1. INTRODUCTION

Malaria remains the world most devastating human parasitic infection, afflicting more than 500 million people and causing about 2.5 million deaths each year. Malaria chemotherapy is challenged by the emergence of drug resistant *Plasmodium falciparum* (Hyde et al., 2005). Recently, artemisinin-based combination therapies (ACTs) were recommended by the World Health Organization (WHO, 2006). However, ACTs face great pharmacological challenges with regard to variable drug bioavailability, drug interactions, and the long half life of partner drugs that have implication in the development of resistant parasite mutants (German & Aweeka, 2008; Kremsner & Krishna, 2005; Talisuna et al., 2004).

Plasmodium falciparum:

Plasmodium falciparum is a protozoan parasite, one of the species of Plasmodium that cause malaria in humans. Malaria caused by this species is the most dangerous form of malaria, with the highest rates of complications and mortality.

Recent reports suggest that, there may already be signs of the emergence of *in vitro* resistance to some artemisinins (Jambou et al, 2005; Uhlemann et al., 2005). This situation indicates that, the battle against malaria could be seriously impaired, until new and efficacious drugs are developed. Chlorophyll containing organisms known to have more than 20,000 species. The macro-algae can produce bioactive compounds like antibiotics, algicides, toxins. A lot of antibiotics have been isolated from algae and show great chemical diversity (fatty acids, bromophenols, tannins, terpenoids, polysaccharides, alcohols). Most of them produce neurotoxic and hepatotoxic compounds (Metting 1996). The important form like Irish moss and carrageenan contain proteins, vitamin A, sugar, starch, vitamin B1, iron, sodium, phosphorous, magnesium, copper and calcium. They all have industrial applications as anticoagulants, antibiotics, antihypertensive agents, blood cholesterol reducers, dilatory agents, insecticides, anti-tumorigenic agents and antiplasmodial agents (Kharkwal et al, 2012; Ravikumar, 2011). Considering this great features, the present investigation has been made an attempt to test the antiplasmodial activities of seaweeds of SouthWest coast of India.

2. MATERIALS AND METHODS

2.1 Collection of sea weeds

The seaweeds *Amphiroa anceps* (Red Algae), *Gracilaria corticata* (Red algae), *Sargassum wightii* (Brown Algae), *Padina pavonica* (Brown algae), *Ulva lactuca* (Green algae) and *Valoniopsis pachynema* (Green algae) were collected from SouthWest coast of India, Kanyakumari, Tamil Nadu. The collected samples were washed thrice with tap water and twice with distilled water to remove the adhering associated animals. Voucher specimen was deposited in the herbarium facility (sponsored by the Indian Council of Medical Research, New Delhi) maintained in the Department of Oceanography and Coastal Area Studies, Alagappa University, Thondi Campus, Tamil Nadu, India.

2.2 Extraction of bioactive principles

The samples were cut into pieces and kept for shade drying. Moisture free samples were subjected for percolation by soaking in 3 different polaritic solvents viz., petroleum ether, ethyl acetate and ethanol. After 21 days of dark incubation, the filtrate was concentrated separately by rotary vacuum evaporator (>45°C) and then freeze dried (-80°C) to obtain solvent free solid residue. The extracts of seaweeds were screened for the presence of phytochemical constituents by following the method of Sofowora (1982) and Kepam (1986). The extracts were dissolved in dimethyl sulphoxide (Hi media Laboratories Private Limited, Mumbai, India) and filtered through sterile millipore filters (mesh 0.20 µm, Sartorius Stedim Biotech GmbH, Germany). The filtrate was used for testing at different concentrations (100, 50, 25, 12.5, 6.25 and 3.125 µg.ml⁻¹) (Jacob inbaneson et al., 2012).

2.3 Culture maintenance

The *in vitro* antiplasmodial activity of seaweed extracts was assessed against *P. falciparum* (obtained from the Jawaharlal Nehru Centre for Advanced Scientific Research, Indian Institute of Science, Bangalore, India). *P. falciparum* were cultivated in human O Rh⁺ red blood cells using RPMI 1640 medium (HiMedia Laboratories Private Limited, Mumbai, India) (Moore et al., 1967) supplemented with O Rh⁺ serum (10%), 5% sodium bicarbonate (HiMedia Laboratories Private Limited, Mumbai, India) and 40 µg. ml⁻¹ of gentamycin sulphate (HiMedia Laboratories Private Limited, Mumbai, India). Haematocrits were adjusted at 5% and parasite cultures were used when they exhibit 2% parasitaemia (Trager, 1987).

2.4 In vitro antiplasmodial activity

Different concentrations of filter-sterilized crude extract from seaweeds (100, 50, 25, 12.5, 6.25 and 3.125 µg ml⁻¹) was incorporated into 96-well tissue culture plate containing 200 µl of *P. falciparum* culture with fresh red blood cells diluted to 2% haematocrit. Negative control was maintained with fresh red blood cells and 2% parasitized *P. falciparum* diluted to 2% haematocrits and positive control was maintained with parasitized blood culture treated with Artemether and chloroquine (Azas et al., 2002). Parasitaemia was evaluated after 24 h and 48 h by giemsa stain and the average percentage suppression of parasitaemia was calculated by the following formula: average % suppression of parasitaemia= average % parasitaemia in control–average % parasitaemia in test/average % parasitaemia in control×100.

2.5 Antiplasmodial activity calculation and analysis

The antiplasmodial activity of seaweed extracts expressed by the inhibitory concentrations (IC_{50}) of the drug that induced 50% reduction in parasitaemia compared to the control (100% parasitaemia). The IC_{50} values were calculated (Concentration of extract in the X-axis and percentage of inhibition in the Y - axis) using office XP (SDAS) software. This activity was analyzed in accordance with the norms of antiplasmodial activity of Rasoanaivo et al., (1992) and suggested that, an extract is very active if $IC_{50} < 5 \mu\text{g ml}^{-1}$, active $IC_{50} < 50 \mu\text{g ml}^{-1}$, weakly active $IC_{50} < 100 \mu\text{g ml}^{-1}$ and inactive $IC_{50} > 100 \mu\text{g ml}^{-1}$.

2.6 Chemical injury to erythrocytes

To assess any chemical injury to erythrocytes that might attributed by the extract, 200 μl of erythrocytes was incubated with 100 $\mu\text{g ml}^{-1}$ of the extract at a dose equal to the highest used in the antiplasmodial assay. The conditions of the experiment were maintained as in the case of antiplasmodial assay. After 48 h of incubation, thin blood smears were stained with giemsa stain and observed for morphological changes under high-power light microscope. The morphological findings were compared with those erythrocytes that were uninfected and not exposed to extract (Waako et al., 2007).

3. RESULTS

Among the seaweed extracts tested, the crude extract of *S. wightii* and *V. pachynema* exhibited maximum activity ($IC_{50} < 3.125 \mu\text{g.ml}^{-1}$) at 48 hrs of incubation in all the three different polaritic solvent. The petroleum ether, ethyl acetate and ethyl alcohol extract of *G.corticata* showed the IC_{50} value of 8.93 $\mu\text{g.ml}^{-1}$, 29.76 $\mu\text{g.ml}^{-1}$ and 22.98 $\mu\text{g.ml}^{-1}$ respectively at 48 hrs (Table 1). Statistical analysis reveals that, the significant *in vitro* antiplasmodial activity ($P < 0.05$) was observed between the concentration and time of exposure. The chemical injury to erythrocytes was done and its shows no morphological changes in erythrocytes by all the three solvent extracts. The preliminary phytochemical analysis of seaweed extracts showed a variety of phytochemical constituents viz., alkaloids, carboxylic acids, coumarins, flavonoids, quinones, phenols, saponins, proteins, resins, steroids tannins and sugars (Table 2).

4. DISCUSSION

The development of parasitic resistance to frontline antimalarial drugs such as Chloroquine, antifolates and recently ART has underscored the importance of developing new drugs and drug targets to treat the disease. The continuous appearance of drug resistant *P. falciparum* strains has made the chemotherapeutic management of malaria increasingly problematic in virtually all malarious regions of the world. ART is a key ingredient in combination drug therapies recommended by the WHO for the treatment of multidrug resistant strains of *falciparum* malaria. Intense efforts are ongoing to develop ART-based combination therapies (ACTs) to extend the life of existing drugs, while major initiatives are underway to discover new antimalarials. The macro algal populations of the aquatic environments provide a vast genetic resource and biodiversity. Scientists confirmed that, algae can be utilized in a completely different manner in the drug industry. *Acochyta salicornniae* was isolated from, green alga *Ulva* species and found to produce unprecedented and structurally unusual tetrameric acid contiguous metabolites ascosalipyrrolidinones A61 & B62. The ascosalipyrrolidinones A61 has antiplasmodial activity towards *Plasmodium falciparum* strains K1 and NF54 (Osterhage et al., 2000). In the recent research it is found that, algae based proteins can inhibit the entry of the HIV virus. Seaweed extracts showed various bio potential activities such as antibacterial (Ravikumar et al, 2002, 2005, 2009; Suresh kumar et al., 2002; Shehnaz 2003;) antifungal (Ravikumar et al., 2009; Aruna et al, 2010) Antiviral (Ponce et al., 2003) Anti-inflammatory (Tan et al., 2000; Jothibai Margret et al., 2009) Termicidal (Ravikumar et al., 2011a) Larvicidal (Syed ali et al., 2013; Ravikumar et al., 2011d) and Spermicidal (Prakash 2004) Antiplasmodial (Ravikumar et al., 2011b, 2011c;). Considering these great features, the present study has been made an attempt to test the antiplasmodial potential of seaweed extracts of SouthWest Coast of India. Among the seaweed extracts tested, the extract of *S. wightii* exhibited excellent antiplasmodial activity by $IC_{50} < 3.125 \mu\text{g ml}^{-1}$. Based on Rasoanaivo et al (1992) recommendation the antiplasmodial compounds were categorized as follows; $IC_{50} < 5 \mu\text{g ml}^{-1}$, active $IC_{50} < 50 \mu\text{g ml}^{-1}$, weakly active $IC_{50} < 100 \mu\text{g ml}^{-1}$ and inactive $IC_{50} > 100 \mu\text{g ml}^{-1}$. In this present study, the petroleum ether, ethyl acetate and ethanolic extract of *S.wightii* exhibited very active inhibition of *P. falciparum* parasites. The existence of antiplasmodial activities of this seaweed extract might be due to the presence of unique chemical classes such as alkaloids, flavonoids, sugars (polysaccharides), and phenolic compounds (Andrews et al., 2005). The antiplasmodial activities of sugars (polysaccharides) were proved to have good merozoites inhibitory activity in *P. falciparum* (Adams et al., 2005) and rosettes disruption activities (Rowe et al., 1994). Moreover, the phenolic compounds from plant extracts also proved to have *in vitro* antiplasmodial activity (Stierle et al., 1988). The polyphenols are also well documented to treat chronic diseases such as cardiovascular disease, cancer, diabetes, bacterial and parasitic infections (Sherman & Billing, 1999; Cowan, 1999). The mechanism of action might be due to the inhibition of *P. falciparum* merozoites invasion into erythrocytes (Adams et al., 2005) or distruption of *P. falciparum* rosettes (Carlson et al., 1992; Rowe et al., 1994) or inhibition of *P. falciparum* fatty acid biosynthesis (Tasdemir et al., 2007). Karl Gademann and Joanna Kobylinska (2009) reported that alkaloids and polyketides were found to be the major substances with antimalarial activity isolated from chordata. It was reported that the ethanolic extracts of seaweed *Caulerpa toxifolia* exhibited the antiplasmodial activity of IC_{50} 5.06 $\mu\text{g.ml}^{-1}$ and *Caulerpa peltata* IC_{50} value of 16.69 $\mu\text{g.ml}^{-1}$ (Ravikumar et al., 2011b). And also it was reported that the methanolic extract of seaweed *Chaetomorpha antennina* showed the antiplasmodial activity of IC_{50} 26.37 $\mu\text{g.ml}^{-1}$ (Ravikumar et al., 2011b). McPhail et al., (2007) reported that, the linear alkynoic lipopeptides, dragomabin have been isolated from a red Panamanian strain of the marine micro algae (blue-green algae) *Lyngbya majuscula* and showed good antimalarial activity ($IC_{50} = 6 \mu\text{M}$) against chloroquine-resistant *Plasmodium falciparum*. Similar findings were reported by several authors

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(Sanon et al., 2003; Son et al., 2007; Moon et al., 2007; Chung et al., 2008; Lee et al., 2009; Ravikumar et al., 2010; Ramazani et al., 2010; Jacob Inbaneson and Ravikumar, 2012). The present finding shows better activity, when comparing with those above mentioned reports in the recent research it is found that, algae based proteins can inhibit the entry of the HIV virus.

5. CONCLUSION

The present study reveals that, the petroleum ether, ethyl acetate and ethyl alcohol crude extract of *V. pachynema* and *S. wightii* collected from Southwest coast of India has effective antiplasmodial protein rich compounds to treat the *falciparum* malaria.

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CONFLICT OF INTEREST STATEMENT

We declare that we have no conflict of interest.

REFERENCES

1. Adams Y, Smith SL, Schwartz-Albiez R, Andrews KT. Carrageenans inhibit the in vitro growth of Plasmodium falciparum and cytoadhesion to CD36. Parasitology Research; 2005, 97: 290-294.
2. Andrews KT, Klatt N, Adams Y, Mischnick P, Schwartz-Albiez R. Inhibition of chondroitin-4-sulfate-specific adhesion of Plasmodium falciparum infected erythrocytes by sulfated polysaccharides. Infection and Immunity; 2005, 73:4288-4294
3. Azas N, Laurencin N, Delmas F, Di Giorgio C, Gasquet M, Laget M, Timon David P. Synergistic in vitro antimalarial activity of plants extracts used as traditional herbal remedies in Mali. Parasitology Research; 2002, 88(2): 165-171.
4. Carlson J, Ekre H P, Helmby H, Gysin J, Greenwood BM, Wahlgren M. Disruption of Plasmodium falciparum erythrocyte rosettes by standard heparin and heparin devoid of anticoagulant activity. The American Journal of Tropical Medicine and Hygiene; 1992, 46:595-602.
5. Cowan MM. Plants products as antimicrobial agents. Clinical Microbiology Review; 1999, 12: 564-582.
6. Feegan, GW., Noor, AM, Akhwale WS, Cousens, S and Snow RW. Effect of expanded insecticide-treated bednet coverage on child survival in rural Kenya: a longitudinal study. The Lancet; 2007, 370 (9592), 1035-9.
7. German PI and Aweeka FT. Clinical pharmacology of artemisinin-based combination therapies. Clinical Pharmacokinetics; 2008, 47, 91-102.
8. Hyde JE. Drug-resistant malaria. Trends in Parasitology; 2005, 21, 494-8.
9. Harsha Kharkwal, Joshi, Preeti Panthari DD, Mnish Kant Pant, Amit Kharkwal C. Algae as future drugs. Asian Journal of Pharmaceutical and Clinical Research, 2012, 5, 4, 1-4
10. Jacob Inbaneson S, Ravikumar S. In vitro Antiplasmodial activity of marine sponge Stylissa carteri associated bacteria against Plasmodium falciparum. Asian Pacific Journal of Tropical Medicine; 2012, 1-5
11. Jambou, R, Legrand, E, Niang, M, Khim, N, Lim, P, Volney, B, Ekala, M T, Bouchier, C, Esterre P, Fandeur T and Mercereau-Puijalon O. Resistance of Plasmodium falciparum field isolates to in-vitro artemether and point mutations of the SERCA-type PfATPase6. The Lancet, 2005, 366, 1960-1963.
12. Jothibai Margret R, Kumaresan S, Ravikumar S. A preliminary study on the anti-inflammatory activity of methanol extract of Ulva lactuca in rat. Journal of Environmental Biology ; 2009, 30(5):899-902.
13. McPhail KL, Correa RG, Linington J Gonzalez, Ortega-Barria E, Capson TL, Gerwick WH. Antimalarial linear lipopeptides from a Panamanian strain of the marine cyanobacterium Lyngbya majuscula., Journal of Natural Product Research, 2007, 70, 984-988.
14. Karl Gademann and Joanna Kobylinska. Antimalarial Natural Products of Marine and Freshwater Origin. John Wiley & Sons, Inc, and the Japan Chemical Forum; 2009.
15. Kepam W. Qualitative organic analysis (Spectrochemical techniques). Ed. II. McGraw Hill, London, 1986, 40-58.
16. Kremsner PG and Krishna S. Antimalarial combinations. The Lancet 2005, 364, 285-294.
17. Metting FB. Biodiversity and application of microalgae. Journal of Industrial Microbiology and Biotechnology; 1996; 17: 477-489
18. Moon HI, Jung JC, Lee J. Antiplasmodial activity of triterpenoids isolated from whole plants of Viola genus from South Korea. Parasitology Research 2007; 100: 641-644.
19. Moore GE, Gerner RE, Frankin HA. Cultures of normal human leukocytes. Journal of American medical Association.; 1967, 199:519-524.
20. Osterhage C, Kaminsky R, Koeing GM, Wright AD. Ascocalipyrrolidinone A, An antimicrobial alkaloid, from the obligate marine fungus Ascochyta salicorniae. Journal of Organic Chemistry; 2000, 65, 6412-6417.
21. Ponce NMA, Pujol CA, Damonte EB, Flores ML, Stortz CA. Fucoicidans from the brown seaweed Adenocystis utricularis: extraction methods, antiviral activity and structural studies. Carbohydrate Research; 2003, 338:153-165.
22. Prakash S. In vitro studies on male antifertility compounds from seaweed marine halophytes. M.Sc. Dissertation, Manonmaniam Sundaranar University, India; 2004.
23. Pandurangan Aruna, Periasamy Mansuya, Sekaran Sridhar, Jebamalai Suresh Kumar and Sarangam Babu. Pharmacognostical and antifungal activity of selected seaweeds from Gulf of Mannar region. Recent Research in Science and Technology, 2010, 2(1): 115-119
24. Ramazani A, Sardari S, Zakeri S, Vaziri B. In vitro antiplasmodial and phytochemical study of five Artemisia species from Iran and in vivo activity of two species. Parasitology Research 2010; 107: 593-599.
25. Rasoanaivo P, Ratsimamanga Urverg S, ramanitrasimbola D, Rafatro H, Rakoto Ratsimamanga A. Criblage d' extraits de plantes de Madagascar pour recherché d' activite antipaludique et d' effet potentialisateur de la chloroquine. Journal of Ethnopharmacology; 1992, 64: 117- 126.
26. Ravikumar S, Anburajan L, Ramanathan G, Kaliaperumal N. Screening of seaweed extracts against antibiotic resistant post operative infectious pathogens. Seaweed Resources Utilization Association; 2002, 24(1):95-99.
27. Ravikumar S, Nazar S, Nural Shiefa A, Abideen S. Antibacterial activity of traditional therapeutic coastal medicinal plants against some pathogen. Journal of Environmental Biology; 2005, 26:383-386.
28. Ravikumar S, Ramanathan G, Subhakaran M, Jacob Inbaneson S. Antimicrobial compounds from marine halophytes for silkworm disease treatment. International Journal of Medical Sciences; 2009, 1(5):184-191.
29. Ravikumar S, Syed Ali M, Saravanan V, Venkatesan M. Termicidal activity of seaweed extracts against Glyptotermis sp. (Isoptera:Termitidae). International Journal of Current Research, 2011a, 3(11): 304-307.
30. Ravikumar S, Ramanathan G, Gnanadesigan M, Ramu A, Vijayakumar V. In vitro antiplasmodial activity of methanolic extracts from seaweeds of South West coast of India. Asian Pacific Journal of Tropical Medicine; 2011b, 862-865.
31. Ravikumar S, Jacob Inbaneson S and Suganthi P. Seaweed as a source of lead compounds for the development of new antiplasmodial drugs from South East Coast of India. Parasitology Research; 2011c; 109: 47-52.
32. Ravikumar S, M Syed Ali, Margaret Beula. Mosquito larvicidal efficacy of seaweed extracts against dengue vector of Aedes aegypti. Asian Pacific Journal of Tropical Biomedicine; 2011, S143-S146

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33. Rowe A, Berendt A R, Marsh K, Newbold C I. Plasmodium falciparum: a family of sulphated glycoconjugates disrupts erythrocyte rosettes. *Experimental Parasitology*; 1994, 79: 506-516.
34. Sanon S, Azas N, Gasquet M, Ollivier E, Mahiou V, Barro N, Cuzin-Ouattara N, Traore A S, Esposito F, Balansard G, Timon-David P. Antiplasmodial activity of alkaloid extracts from *Pavetta crassipes* (K. Schum) and *Acanthospermum hispidum* (DC), two plants used in traditional medicine in Burkina Faso. *Parasitology Research*, 2003, 90(4):314-7.
35. Shehnaz L. Comparative phytochemical investigations on a variety of marine algae from Karachi coast. Ph.D. Dissertation, University of Karachi, Pakistan, 2003.
36. Sherman P W and Billing J. Darwinian gastronomy: Why we use spices. *Bioscience*; 1999, 49: 453-463.
37. Sofowora A. Medicinal plants and traditional medicine in Africa. Wiley, New York, 1982, 251.
38. Stierle AC, Cardellina JHI, Singleton FL. A marine *Micrococcus* produces metabolites ascribed to the sponge *Tedania ignis*. *Experientia journal*; 1988, 44: 1021.
39. Suresh Kumar S, John JAC, Ravikumar S. Antimicrobial activity of acetone extracts of seaweeds against human pathogens. *Seaweed Resources Utilization*; 2002, 24:111–115
40. Mohamed Yacoob Syed Ali, Sundaram Ravikumar and Johanson Margaret Beula. Mosquito larvicidal activity of seaweeds extracts against *Anopheles stephensi*, *Aedes aegypti* and *Culex quinquefasciatus*. *Asian Pacific Journal Tropical Disease*; 2013, 3(3): 196–201.
41. Talisuna AO, Bloland P and D Alessandro U. History, dynamics, and public health importance of malaria parasite resistance. *Clinical Microbiology Reviews*; 2004, 17, 235–254.
42. Tan LT, Williamson RT, Gerwick WH, Watts KS, McGough K, Jacobs R. cis, cis- and trans, trans-Ceratospongamide, new bioactive cyclic heptapeptides from the Indonesian Red Alga *Ceratodictyon spongiosum* and symbiotic Sponge *Sigmadocia symbiotica*. *Journal of Organic Chemistry*; 2000, 28:419–425.
43. Tasdemir D, Topaloglu B, Perozzo R, Brun R, O'Neil R, Carballicira N M. Marine natural products from the Turkish sponge *Agela oroides* that inhibit the enoyl reductases from *P.falciparum*, *Mycobacterium tuberculosis* and *Escherichia coli*. *Bioorganic & Medicinal Chemistry*; 2007, 15: 6834-6845.
44. Trager W. The cultivation of *Plasmodium falciparum*: applications in basic and applied research in malaria. *Annals of Tropical Medicine and Parasitology*; 1987, 81:511–529.
45. Uhlemann A C, Cameron A, Eckstein-Ludwig, U, Fischbarg, J, Iserovich, P, Zuniga, FA, East, M, Lee, A, Brady, L, Haynes, RK and Krishna, S. A single amino acid residue can determine the sensitivity of SERCAs to artemisinin. *Journal of Nature Structural & Molecular Biology*; 2005, 12, 628-629.
46. Waako PJ, Katuura E, Smith P, Folb P. East African medicinal plants as a source of lead compounds for the development of new antimalarial drugs. *African Journal of Ecology*; 2007 45(1):102–106.
47. World Health Organization. Briefing on Malaria Treatment Guidelines and artemisinin monotherapies, Geneva, 19 April; 2006.

Table 1

 IC₅₀ values of chosen seaweed extracts against *Plasmodium falciparum*

S. No	Names of the Seaweeds	Suppression of Parasitaemia IC ₅₀ at 24 hrs			Suppression of Parasitaemia IC ₅₀ at 48 hrs		
		Petroleum ether	Ethyl acetate	Ethyl alcohol	Petroleum ether	Ethyl acetate	Ethyl alcohol
1.	<i>A. anceps</i>	81.10	88.37	71.90	61.25	81.59	65.12
2.	<i>G. corticata</i>	42.35	62.70	38.96	26.85	51.07	17.17
3.	<i>S. wightii</i>	28.79	<3.125	10.39	<3.125	<3.125	<3.125
4.	<i>P. pavonica</i>	42.84	54.95	37.51	8.93	29.76	22.98
5.	<i>U. lactuca</i>	90.31	64.15	41.39	77.23	55.92	31.21
6.	<i>V. pachynema</i>	11.35	<3.125	<3.125	<3.125	<3.125	<3.125

Table 2

Positive controls

S. No	Sample name	Suppression of Parasitaemia IC ₅₀ at 24 hrs	Suppression of Parasitaemia IC ₅₀ at 48 hrs
1.	Chloroquine	<3.125	<3.125
2.	Artemether	<3.125	<3.125

Table 3

Phytochemical constituents of chosen seaweeds

S. No	Names of the seaweeds	Solvents	Alkaloids	Carboxylic acid	Coumarins	Flavonoids	Quinones	Phenols	Saponins	Xantho proteins	Proteins	Resins	Steroids	Tannins	Sugars	
1.	<i>A. anceps</i>	Petroleum ether	-	-	-	-	-	-	-	+	+	-	-	-	-	
		Ethyl acetate	-	-	-	-	-	-	-	-	+	-	-	-	-	
		Ethyl alcohol	+	-	-	+	+	+	-	-	+	+	-	+	-	+
2.	<i>G. corticata</i>	Petroleum ether	-	-	-	-	-	-	-	+	+	-	-	-	-	
		Ethyl acetate	-	-	-	-	-	-	-	-	+	+	-	-	-	-
		Ethyl alcohol	+	+	+	+	-	-	-	-	-	+	-	-	-	+
3.	<i>S. wightii</i>	Petroleum ether	-	-	-	-	-	-	-	-	-	-	-	-	-	
		Ethyl acetate	-	-	-	-	-	-	-	-	-	+	-	-	-	-
		Ethyl alcohol	-	-	-	-	-	-	+	-	-	+	+	-	-	-
4.	<i>P. pavonica</i>	Petroleum ether	-	-	-	-	-	-	-	-	+	-	-	-	-	
		Ethyl acetate	-	-	-	-	-	-	-	-	-	+	-	-	-	-
		Ethyl alcohol	+	-	-	-	-	-	+	-	-	-	+	-	-	+
5.	<i>U. lactuca</i>	Petroleum ether	-	-	-	-	-	-	-	+	+	-	-	-	-	
		Ethyl acetate	-	-	-	-	-	-	-	-	+	+	-	-	-	-
		Ethyl alcohol	-	-	-	-	-	-	-	-	-	-	-	-	-	+
6.	<i>V. pachynema</i>	Petroleum ether	-	-	-	-	-	-	-	+	+	-	-	-	-	
		Ethyl acetate	-	-	-	-	-	-	-	-	+	+	-	-	-	-
		Ethyl alcohol	-	+	-	-	-	-	+	-	-	-	+	-	-	+

(+) Presence**(-) Absence**