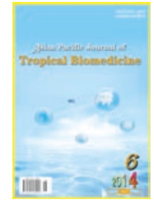
Asian Pacific Journal of Tropical Biomedicine

journal homepage: www.apjtb.com



Document heading doi:10.12980/APJTB.4.2014C1255

A recent review on phytochemical constituents and medicinal properties of kesum (*Polygonum minus* Huds.)

Paritala Vikram[1], Kishore Kumar Chiruvella[2], Ilfah Husna Abdullah Ripain[1], Mohammed Arifullah[1*]

[1]*Faculty of Agro Based Industry, Universiti Malaysia Kelantan, Campus Jeli, Locked Bag No. 100, 17600, Jeli, Kelantan, Malaysia*

[2]*Department of Molecular Biosciences, Stockholm University, Sweden*

PEER REVIEW

Peer reviewer
Assoc Prof. Dr. Gan Siew Hua, Human Genome Centre, School of Medical Sciences, Universiti Sains Malaysia, 16150 Kubang Kerian, Kelantan, Malaysia.
Tel: +6097676803
E-mail: shgan@usm.my

Comments
This review acts as a valuable note of information regarding the chemical composition and pharmacological uses of *P. minus*. It is providing simple yet efficient data on the topics it covered which is useful for laying ways to newer and intensive researches on *P. minus*.
Details on Page 434

ABSTRACT

Medicinal plants and herbal preparations are gaining renowned interest in scientific communities nowadays due to their reliable pharmacological actions and affordability to common people which makes them effective in control of various diseases. *Polygonum minus* (Polygonaceae) locally known as kesum is an aromatic plant commonly used in Malay delicacies. The plant is having potential applications due to its high volatile oil constituents in perfumes and powerful antioxidant activity. It has been used traditionally to treat various ailments including dandruff. The research has been carried out by various researchers using different *in vitro* and *in vivo* models for biological evaluations to support these claims. This review paper may help upcoming research activities on *Polygonum minus* by giving up to date information on the phytochemical constituents and medicinal properties of kesum to a possible extent with relevant data.

KEYWORDS
Malay herbs, Polygonaceae, Pharmacological properties, Phytochemical constituents, Pigmy knot weed

1. Introduction

Polygonum minus (*P. minus*) is commonly known as pigmy knot weed in English and kesum in Malay[1] which belongs to the family Polygonaceae. This plant has sweet and nice aroma hence commonly used as flavoring ingredient in preparation of ulam (salad), laksa and several other Malay food delicacies. The plant is found in Southeast Asian countries namely Malaysia, Indonesia, Thailand (Phak pai) and Vietnam. The plant produces essential oil containing high levels of aliphatic aldehydes (72.54%)[2]; and it has been recognized by the Malaysian government as an essential oil-producing crop in the Herbal Product Blueprint[3]. The plant is found growing wild especially in damp areas such as the side ditches or nearby rivers and lakes. *P. minus* is a slender, creeping shrub and can reach up to a height of 1.0 m in lowland and up to 1.5 m in the highlands. The leaves are narrow and lanceolate,

*Corresponding author: Mohammed Arifullah, Senior lecturer, Address: Faculty of Agro Based Industry, Universiti Malaysia Kelantan, Campus Jeli, Locked Bag No. 100, 17600, Jeli, Kelantan, Malaysia.
Tel: +6097717166
Fax: +6099467158
E-mail: arifullahmd@gmail.com
Foundation project: Financially supported by Universiti Malaysia Kelantan (Grant No. R/SGJP/A07.00/00710A/001/2012/000081).

Article history:
Received 31 Mar 2014
Received in revised form 7 Apr, 2nd revised form 12 Apr, 3rd revised form 20 Apr 2014
Accepted 29 Apr 2014
Available online 28 Jun 2014

5–7 cm long and 0.5–2.0 cm wide (Figure 1), dark green in color and very aromatic and arranged in alternate manner on the stem. The stem is cylindrical, dark green with a little reddish color with short internodes and nodal segments of simple roots[4]. Inflorosence is apical, flowers are small white purple-colored 1.5 to 2.0 mm long and lenticular black or dark brown coloured fruits.

Figure 1. Image of *P. minus* along with inflorescence enlarged.

Traditionally *P. minus* has been used in herbal medicine as a cure for digestive disorders and dandruff in Malaysia despite of its regular uses as food flavoring agent and appetizer in Malays cuisine. The essential oil extracted from *P. minus* leaves is applied to hair to remove dandruff, used in aroma therapy[5] and in the perfume industry[4]. *P. minus* has also been reported to possess several pharmacological properties like antimicrobial activity[6], cytotoxic activity against HeLa (human cervical carcinoma)[7], antioxidant activity[8] and anticancer activity[9,10]. The aim of this paper is to review the recent reports on phytochemical constituents and medicinal properties of *P. minus* which may help future researchers working with this plant.

2. Phytochemical constituents

Plant-produced chemical compounds or phytochemicals like alkaloids, glycosides, flavonoids, volatile oils, tannins, resins have been used in a wide range of commercial and industrial applications such as flavors, aromas and fragrances, enzymes, preservatives, cosmetics, bio based fuels and plastics, natural pigments and bioactive compounds. The research on phytochemicals and use of phytochemicals is increasing more because of the harmful side effects of the synthetic compounds. Various reports have been published regarding the phytochemical content

Table 1

Phytochemical constituents of *P. minus* reported from plant and *in vitro* cell cultures.

Name of plant material	Name of phytochemical constituents
Leaves	Gallic acid, rutin, coumaric acid, quercetin
Roots	Nonane (1.65), heptane (1.11), octadecanal (3.08), β-caryophyllene (17.57), trans-α-bergamotene (2.13), β-farnesene (2.84), α-caryophyllene (9.50), p-benzoquinone (1.85), phenol (2.73), α-panasinsen (1.82), pentanoic acid (1.47), octane (1.42), heptane (0.44), undecane (0.52), 1,2 benzenedicarboxylic acid (0.52), nonane (0.44)
Callus	2-furanmethanol (0.35), 2 (5H)-furanone (1.75), 2-hydroxy-2-cyclopenten-1-one (6.67), 2,4-dihydroxy-2,5-dimethyl-3(2H)-furan-3-one (0.20), 2H-pyran-2,6 (3H)-dione (0.26), 2-hydroxy-gamma-butyrolactone (3.08), 2,5-dimethyl-4-hydroxy-3 (2H)-furanone (1.93), 2,5-furandicarboxaldehyde (0.98), 2,3-dihydro-3,5-dihydroxy-6-methyl 4H-pyran-4-one (1.66), (S)-(+)-2′,3′-dideoxyribonolactone (0.882), 5-(hydroxymethyl)-furancarboxaldehyde (18.51), 3-deoxy-D-mannoic lactone (19.44)
Essential oil	2-hexenal (0.001), cis-3-hexenal (0.022), decanal (23.121), 1-decanol (2.090), 1-dodecanol (1.380), undecanal (0.990), dodecanal (38.635), 1-dodecanal (4.785), tetradecanal (1.506), hexadecanal (0.004), cyclodecanol (5.691), undecane (2.286), nonane (0.062), nonanal (0.010), 3-carene (1.202), camphene (0.009), sabinene (0.013), 2-butyltetrahydrofuran (0.004), 1-cyclopropylpentane (0.005), isobornyl formate (0.071), α-copaene (0.024), octylcyclopropane (0.001), (z,e)-α-farnesene (0.928), α-cedrene (0.012), (e)-β-caryophyllene (0.212), α-bergamotene (0.801), γ-gurjunene (0.095), α-humulene (2.293), trans-β-farnesene (0.907),2-isopropenyl-4a,8-dimethyl-1,2,3,4,4a,5,6,7-octahydronaphthalene (0.697), α-curcumene (0.080), valencene (0.806), alloaromadendrene (0.039), β-bisabolene (0.014), α-zingiberene (0.013), α-panasinsene (0.563), δ-cadinene (0.025), patchulane (0.004), nerolidol (0.075), caryophyllene oxide (1.513), ocimene (0.055), dehydro-cyclolongifolene oxide (0.544), acoradiene (0.079), 1,3,6,10-dodecatetraene (0.117), 4,4 dimethyltetracyclo [6.3.2.0(2,5). (1,8)] tridecan-9-ol (0.122), drimenol (0.574), phytol (0.003)

*with in brackets is peak percentage of the compound.

of *P. minus* and reported to have different phytochemical compounds. Urones *et al.*[11] isolated two new components from the ether extract of *P. minus* a flavone: 6,7–methylenedioxy–5,3″,4″,5″ tetramethoxyflavone and a methyl flavonol: 6,7–4″,5″dimethylenedioxy–3,5,3″–trimethoxyflavone. Yaacob[12] have reported that the flavor of *P. minus* is due to the presence of decanal (24.36%) and dodecanal (48.18%) mainly, along with them he had isolated 1–decanol, 1–dodecanol, undecanal, tetradecanal, 1–undecanol, nonanal, 1–nonanol and β–caryophyllene. Qader *et al.*[13] showed the presence of phenolic compounds like gallic acid, rutin, coumaric acid and quercetin in leaves. Baharum *et al.*[14] have analysed the essential oil of *P. minus* using Two–Dimensional Gas Chromatography–Time–of–Flight Mass Spectrometry (GC–TOF MS) and identified 48 compounds (Table 1).

Ismail *et al.*[15] studied the presence of phytochemical constituents in *P. minus* root cultures and reported 16 compounds (Table 1). Shukor *et al.*[16] identified 12 chemical compounds in leaf cell cultures which were not present in *P. minus* intact plants (Table 1). Several new compounds like 2,2′–bioxirane; propanoic acid–2oxo–methyl ester; repandin A; 2–propanone, 1,3–dihydroxy–imidazolidine–2,4,5–trione; and 2–acetyl–2–hydroxy–butyrolactone were found in elicitated cell cultures but not found in the control culture.

3. Medicinal properties

Various studies have revealed the different pharmacological potentials of *P. minus* both *in vitro* and *in vivo* test models. *P. minus* have demonstrated to possess cytoprotective, antibacterial, antifungal, antiulcer, antiviral and antioxidant activities. These properties have been described in greater detail in the following subsections.

3.1. Antibacterial activity

Resistance of many bacteria against antibiotics is alarmingly increasing and the side effects associated with the usage of antibiotics are also a major problem in treatment of infectious diseases. Therefore, search for new substances with antimicrobial activity has become an urgent necessity. Medicinal plants have been used in development of drugs from long time and compounds with antimicrobial activity from plant origin are the possible alternative to the problems faced by usage of synthetic antimicrobial compounds. Most of the research in this area is going on development of newer antimicrobials with more potent activity either from the plant derived compounds or from their synthetic analogues. Musa *et al.*[17] showed that *P. minus* aqueous extract had no significant activity against 10 isolated pathogenic fish bacteria namely *Aeromonas hydrophila, Citrobacter freundii, Edwardsiella tarda, Escherichia coli* (*E. coli*), *Staphylococcus aureus* (*S. aureus*), *Streptococcus agalatiae, Streptococcus aginosus, Vibrio alginolyticus, Vibrio parahaemolyticus* and *Vibrio vulfinificus*. Jamal *et al.*[18] also reported that the distilled water extract of *P. minus* did not show any activity on *Bacillus subtilis* (*B. subtilis*) and *E. coli* however ethanolic and methanolic extracts showed activity against *B. subtilis* and no activity on *E. coli*. On the contrary Haasim *et al.*[19] reported that *P. minus* water extract showed activity on *E. coli* but did not show any activity on *B. subtilis* and *S. aureus* while ethanol and methanol extracts showed good activity on *B. subtilis*, *S. aureus* and *E. coli*. Further, Nurul *et al.*[20] demonstrated that the aqueous extracts of *P. minus* were slightly more effective in preventing microbial growth on refrigerated duck meatballs.

3.2. Antifungal activity

Johnny *et al.*[21] carried out a study on antifungal activity of 15 plants incliuding *P. minus* using *Colletotrichum capsici* isolated from chillies as test organism and reported that methanolic extract shown activity against *Colletotrichum capsici*. Ong *et al.*[22] reported that when *P. minus* was made into a paste and mixed with kerosene and applied on the skin to get rid of the fungal infections.

3.3. Antiviral activity

Plants have had a long evolution of resistance against viral agents and laid alternative ways in drug development to treat viruses. Extensive studies have shown that medicinal plants contain compounds active against viruses that cause human diseases. Therefore, plant extracts and phytochemicals are getting more importance as potential source for viral inhibitors. Ali *et al.*[9] reported the antiviral properties of *P. minus* against herpes simplex variety 1 and vesicular stomatitis virus. The ethanolic extract of *P. minus* had shown strong antiviral against herpes simplex variety 1 and weak activity against vesicular stomatitis virus.

Table 2

Medicial properties of *P. minus*.

Medicinal property	Extracts used	References
Antibacterial activity	Ethanol, Methanol	[17]
	Ethanol, Methanol, Distilled water	[18]
	Distilled water	[19]
Antifungal activity	Methanol	[20]
	Mixed with kerosene	[21]
Antioxidant activity	Plant juice	[23]
	Distilled water	[22]
	Distilled water	[19]
	Methanol	[8]
	Ethanol, Distilled water	[24]
	Ethanol, Methanol, Distilled water, Methanol 50%, Methanol 70%, Ethanol 50%, Ethanol 70%	[18]
	Distilled water	[26]
Antiulcer activity	hexane:ethyl acetate 1:1 v/v, ethyl acetate:methanol 1:1 v/v, methanol:acetonitrile 1:1 v/v, acetonitrile:distilled water 1:1 v/v, Distilled water	[27]
	Petroleum ether, methanol and chloroform	[9]
Avtiviral activity	Ethanol	[10]
Acute Toxicity	Distilled water	[28]
Cytotoxicty	Petroleum ether, methanol and chloroform	[9]
Cytoprotectivity	Distilled water	[26]

3.4. Antioxidant activity

It is now well known that the generation of free radicals or reactive oxygen species from incomplete reduction of molecular oxygen during aerobic respiration is closely related to cellular damage. Regulation of the balance between the production of reactive oxygen species by cellular processes and its removal by antioxidant defense system maintains normal physiological processes. Antioxidant compounds in food play an important role as a health protecting factor in diseases like cancer, coronary heart diseases and they are also used as natural food preservatives. *P. minus* is considered as a potential source of natural antioxidants due to high content of gallic acid, total phenolic content and reducing power[5,23]. Maizura *et al.*[24] extracted *P. minus* by using juice extractor without adding any additional solvent and reported to have high antioxidant property. Aqueous extract of *P. minus* has shown good antioxidant properties and there was no significant difference with synthetic antioxidant (butyl hydroxyl toluene) (BHT)[23]. Nurul *et al.*[20] reported that *P. minus* aqueous extract showed potential antioxidant effects on duck meatballs and gave better results when compared to synthetic antioxidant BHT. Methanolic extract of *P. minus* showed no significant difference with butyl hydroxyl anisole and was superior to BHT in reducing Fe (III) to Fe (II)[25]. In another report *P. minus* ethanol extract showed higher antioxidant activity when compared to aqueous extract and there is no significant difference with synthetic antioxidant gallic acid[26]. *P. minus* is extracted with water, ethanol and methanol in different concentrations and 70% methanol showed more activity than rest of extracts and the yield of extract is also more for 70% methanol[19]. All these results clearly indicate that difference in solvents used for preparing the extract affect the antioxidant activity[27].

3.5. Antiulcer activity

Peptic ulcer is one of the common diseases affecting nearly 10% of world population and the treatment for this disease have to be improved more than the existing therapies because of the side effects. For common problems like gastric ulcers it is better to use plant derived preparations as they can be easily available and most of the plants are even consumed in daily diet. The efficiency of some extracts in liquid medium and at low pH levels enhances their potency even in the human stomach make them more reliable. Oral administration of *P. minus* aqueous extract at dose of 250 and 500 mg/kg body weight both in normal and rats with ethanol induced ulcers showed significant inhibition of ulcerous areas in a concentration dependent manner and there was no significant difference with omeprazole used as reference[28]. Qader *et al.*[13] reported that ethyl acetate: methanol 1:1 fraction of *P. minus* was shown to have gastroprotective activity against oxidative stress caused by ethanol induction and all the fractions of ethanol extract significantly significantly reduced the area of ulceration when compared with the carboxy methyl cellulose. The presence of phenolic compounds like gallic acid and coumaric acid is responsible for gastroprotective activity[29]. *In vitro* anti *Helicobacterium pylori* tests of *P. minus* were carried out along with 32 selected medicinal plants used in Malaysian traditional medicine for gastrointestinal disorders and wounds. High zone of inhibition was observed against H. pylori using *P. minus* petroleum ether (15.5 mm), methanol (15.5 mm) and chloroform (12.3 mm) extracts whereas no inhibition zone was speculated in aqueous extract[6].

3.6. Acute toxicity and cytoprotectivity

Studies on acute toxicity of a plant drug are essential to assess the toxic effects of plant preparations on human health. Acute toxicity studies of compounds are generally carried out in animals or *in vitro* models. Acute toxicity of *P. minus* was assessed and no mortality was observed in rats fed with *P. minus* extracts. Histological observation of the liver and kidneys for any changes or modifications indicated no alteration to the treated organs and serum biochemistry revealed that there was no significant difference between the test and control groups. It is concluded that the extract was quite safe even at higher doses and had no acute toxicity[28]. Wasman *et al.*[28] reported that the aqueous extract of *P.*

minus has cytoprotective properties.

3.7. Cytotoxicity and genotoxicity

Cytotoxic studies are carried out to reveal the toxic effect of plant extracts or drugs when consumed by humans and cytotoxic activities can also used for assessing anticancer activity of the extracts. Ali *et al*.[9] reported that *P. minus* demonstrated cytotoxicity (50% cytotoxic dose or CD_{50}: 0.1 mg/mL) against HeLa cells while *P. minus* has been assessed against normal lung fibroblast cell line Hs888Lu and the results did not present any inhibition percentage of cell viability in both ethanol and aqueous extracts[26]. Genotoxic studies are used to determine the doses of plant extracts or drugs that either damage DNA or alter basic cellular pathways important for maintaining genomic integrity. Wan-Ibrahim *et al*.[30] has proved that aqueous extract of *P. minus* has no genotoxic effect on human lymphocytes.

4. Conclusion

In the present paper, we have reviewed the relevant literature to congregate the phytochemicals, secondary metabolites and pharmacological information on *P. minus*. The presence of decanal, dodecanal and many other aldehydes make *P. minus* a major source of perfume. The phenolic compounds like gallic acid and coumaric acid are responsible for many activities including antioxidant and antiulcer activity. Antioxidant studies revealed the potential of *P. minus* as a food preservative and antioxidant. Compounds isolated from *P. minus* callus cell culture such as 5-hydroxymethyl-furancarboxaldehyde or hydroxymethylfurfural or HMF have inhibition of sickle cell blood production property and repandin A has antidiabetic activity. But these valuable compounds are absent in intact plants which makes cell suspension culture of *P. minus* a valuable tool for production of these compounds. The toxicity studies on *P. minus* concluded that the extracts were quite safe even at higher doses and had no toxic effects on cell lines used.

Conflict of interest statement

We declare that we have no conflict of interest.

Acknowledgements

The authors are highly grateful to the UMK for their logistical support under Grant No. R/SGJP/A07.00/00710A/001/2012/000081.

Comments

Background

P. minus is commonly used in Malaysia as food and medicine. The plant has potential applications in preparation of perfumes, production of volatile oils and potent antioxidant properties. Secondary metabolites produced from the plant are diverse in nature and important both medicinally and industrially. There is a need for detailed description of the plants phytochemical constituents and pharmacological properties to increase awareness and usage of the plant in diverse fields.

Research frontiers

Data from three dimensions of the plant *viz.* phytochemical analysis of intact plant, secondary metabolite analysis from cell cultures and pharmacological studies of the plant.

Related reports

Suhailah Wasman Qader *et al.* published an article about Potential bioactive property of *P. minus* Huds (kesum) review.

Innovations and breakthroughs

Data regarding phytochemicals from cell suspension cultures of *P. minus* are presented here along with phytochemicals from intact plants along with their chemical structures which will give simple yet informative ideas about the plant.

Applications

The key application of this review is providing information about phytochemical and pharmacological properties of the plant which improves the usage of plant for health benefits and stands as a guide for future research on the plant.

Peer review

This review acts as a valuable note of information regarding the chemical composition and pharmacological uses of *P. minus*. It is providing simple yet efficient data on the topics it covered which is useful for laying ways to newer and intensive researches on *P. minus*.

References

[1] Burkill IH. *A dictionary of the economic product of the Malay Peninsula. Vol 2.* Kuala Lumpur, Malaysia: Ministry of Agriculture and Cooperatives; 1966.

[2] Gor MC, Ismail I, Mustapha WAW, Zainal Z, Noor NM, Othman R, et al. Identification of cDNAs for jasmonic acid-responsive genes in *Polygonum minus* roots by suppression subtractive hybridization. *Acta Physiol Plant* 2011; **33**: 283-294.

[3] Wan Hassan WE. *Healing herbs of Malaysia*. Kuala Lumpur: Federal Land Development Authority (FELDA); 2006.

[4] Bunawan H, Talip N, Noor NM. Foliar anatomy and micromorphology of *Polygonum minus* Huds and their taxonomic implications. *Aust J Crop Sci* 2011; **5**: 123-127.

[5] Almey AAA, Khan CAJ, Zahir IS, Suleiman KM, Aisyah MR, Rahim KK. Total phenolic content and primary antioxidant activity of methanolic and ethanolic extracts of aromatic plants leaves. *Int Food Res J* 2010; **17**: 1077-1084.

[6] Uyub AM, Nwachukwu IN, Azlan AA, Fariza SS. *In-vitro* antibacterial activity and cytotoxicity of selected medicinal plant extracts from Penang Island Malaysia on metronidazole-resistant-*Helicobacter pylori* and some pathogenic bacteria. *Ethnobotany Res Appl* 2010; **8**: 95-106.

[7] Mackeen MM, Ali AM, El-Sharkawy SH, Manap MY, Salleh KM, Lajis NH, et al. Antimicrobial and cytotoxic properties of some Malaysian traditional vegetables (Ulam). *Pharm Biol* 1997; **35**: 174-178.

[8] Huda-Faujan N, Noriham A, Norrakiah AS, Babji AS. Antioxidant activity of plants methanolic extracts containing phenolic compounds. *Afri J Biotechnol* 2009; **8**(3): 484-489.

[9] Ali AM, Mackeen MM, El-Sharkawy SH, Abdul Hamid J, Ismail NH, Ahmad F, et al. Antiviral and cytotoxic activities of some plants used in Malaysian indigenous medicine. *Pertanika J Trop Agric Sci* 1996; **19**: 129-136.

[10] Abdullah MZ, Mavaddat MH, Mohd AJ. Antioxidant and anticancer activities of *Polygonum minus*, *Alpinia galanga* and *Etlingera elatior*. *Open Conference Proc J* 2013; DOI: 10.2174/2210289201304010202.

[11] Urones JG, Marcos IS, Pérez BG, Barcala PB. Flavonoids from *Polygonum minus*. *Phytochemistry* 1990; **29**: 3687-3689.

[12] Yaacob KB. Kesom oil-a natural source of aliphatic aldehydes. *Perfum Flavor* 1987; **12**: 27-30.

[13] Qader SW, Abdulla MA, Chua LS, Sirat HM, Hamdan S. Pharmacological mechanisms underlying gastroprotective activities of the fractions obtained from *Polygonum minus* in Sprague Dawley rats. *Int J Mol Sci* 2012; **13**: 1481-1496.

[14] Baharum SN, Bunawan H, Ghani MA, Mustapha WAW, Noor NM. Analysis of the chemical composition of the essential oil of *Polygonum minus* Huds. using two-dimensional gas chromatography-time-of-flight mass spectrometry (GC-TOF MS). *Molecules* 2010; **15**: 7006-7015.

[15] Ismail I, Gor MC, Mohamed-Hussein ZA, Zainal Z, Noor MN. Alteration of abiotic stress responsive genes in *Polygonum minus* roots by jasmonic acid elicitation. In: Vasanthaiah HKN, Kambiranda D, editors. *Plants and environment*. Rijeka, Croatia: InTech-Open Access Company; 2011, p. 49-88.

[16] Shukor MFA, Ismail I, Zainal Z, Noor NM. Development of a *Polygonum minus* cell suspension culture system and analysis of secondary metabolites enhanced by elicitation. *Acta Physiol Plant* 2013; **35**: 1675-1689.

[17] Musa N, Wei LS, Seng CT, Wee W, Leong LK. Potential of edible plants as remedies of systemic bacterial disease infection in cultured fish. *Global J Pharmacol* 2008; **2**: 31-36.

[18] Jamal P, Karim IA, Abdullah E, Raus RA, Hashim YZ. Phytochemical screening for antibacterial activity of potential Malaysian medicinal plants. *Afri J Biotech* 2011; **10:** 18795-18799.

[19] Hassim N, Markom M, Anur N, Bahraum SN. Solvent selection in extraction of essential oil and bio active compounds from *Polygonum minus*. *J Appl Sci* 2013; DOI: 10.3923/jas.2013.

[20] Nurul H, Ruzita A, Aronal AP. The antioxidant effects of *Cosmos caudatus* and *Polygonum minus* in refrigerated duck meatballs. *Int Food Res J* 2010; **17**: 893-904.

[21] Johnny L, Yusuf UK, Nulit R. Antifungal activity of selected plant leaves crude extracts against a pepper anthracnose fungus, *Colletotrichum capsici* (Sydow) butler and bisby (Ascomycota: Phyllachorales). *Afr J Biotech* 2011; **10**: 4157-4165.

[22] Ong HC, Nordiana M. Malay ethno-medico botany in Machang, Kelantan, Malaysia. *Fitoterapia* 1999; **70**: 502-513.

[23] Huda-Faujan N, Noriham A, Norrakiah AS, Babji AS. Antioxidative activity of water extracts of some Malaysian herbs. *ASEAN Food J* 2007; **14**(1): 61-68.

[24] Maizura M, Aminah A, Aida WM. Total phenolic content and antioxidant activity of kesum (*Polygonum minus*), ginger (*Zingiber officinale*) and turmeric (*Curcuma longa*) extract. *Int Food Res J* 2011; **18**: 529-534.

[25] Huda-Faujan N, Noriham A, Norrakiah AS, Babji AS. Antioxidant activity of plants methanolic extracts containing phenolic compounds. *Afr J Biotechnol* 2009; **8**(3): 484-489.

[26] Qader SW, Abdulla MA, Chua LS, Najim N, Zain MM, Hamdan S. Antioxidant, total phenolic content and cytotoxicity evaluation of selected Malaysian plants. *Molecules* 2011; **16**: 3433-3443.

[27] Othman A, Ismail A, Abdul Ghani N, Adenan I. Antioxidant capacity and phenolic content of cocoa beans. *Food Chem* 2007; **100**: 1523-1530.

[28] Wasman SQ, Mahmood AA, Salehhuddin H, Zahra AA, Salmah I. Cytoprotective activities of *Polygonum minus* aqueous leaf extract on ethanol-induced gastric ulcer in rats. *J Med Plants Res* 2010; **4**: 2658-2665.

[29] Matsuda H, Pongpiriyadacha Y, Morikawa T, Ochi M, Yoshikawa M. Gastroprotective effects of phenylpropanoids from the rhizomes of *Alpinia galanga* in rats: structural requirements and mode of action. *Eur J Pharmacol* 2003; **471**: 59-67.

[30] Wan-Ibrahim W, Sidik K, Kuppusamy UR. A high antioxidant level in edible plants is associated with genotoxic properties. *Food Chem* 2010; **122**: 1139-1144.