Phytochemical investigations of *Achyranthes aspera* revealed the presence of steroids, long chain compounds, saponins, alkaloids, flavonoids and others (Varuna *et al.*, 2010; Day 2011; Srivastava *et al*., 2011).

Proximate Composition and Proteins

The sun-dried and dehusked white seeds of *Achyranthes aspera* had the following proximate composition: moisture, 9.1; protein (N x 6.25), 22.5; ether extract, 4.7; carbohydrates, 56.1; ash, 4.6; fiber, 1.8; Ca, 0.10; P, 0.46; Fe, 0.0093% and contained 392 cal./g. Percent amino acid/16 g N was arginine, 2.1; histidine, 4.9; lysine, 3.4; methionine, 2.2; cystine, 2.7; methionine + cystine, 4.9; threonine, 2.3; phenylalanine, 6.2; leucine, 8.6; isoleucine, 5.6, tryptophan, 1.8 and valine, 5.6 (Satyanarayana *et al*., 1964). On the other hand, Noor and Khan (1982) reported that hydroxyproline, valine and methionine were absent from the seeds. The study of the distribution of amino acids in some unconventional leaves used by tribes as foods *viz. Cassia tora* Linn., *Achyranthes aspera* Linn., *Amaranthus blitum* Linn., *Alternanthera sessilis* Br. and *Oxalis corniculata* Linn., revealed that protein content was highest in *Achranthes aspera* (Kaur and Chaturvedi, 2007). The leaves contain 5.3% protein (French, 2006). *Achyranthes aspera* was found to be one of the best suited plants for leaf protein concentrate, a highly nutritious food (Rathore, 2010). The plant has high vitamin A activity (1.75 mg% expressed as retinol equivalent) with total carotenoids and β-carotene amounting to 36.13 and 10.49 mg% respectively (Rajyalakshmi *et al*., 2001). Total sugars, vitamins, amino acids, nitrogen and proteins were estimated by Chauhan *et al*. (2002). The plant contains mucilage (Babu and Elango, 2011).

The ash content of the plant is 5% (dry weight) (Kadam *et al*., 2007). It has been early reported that the ash, which is used in India as an alkali, for washing, dyeing, and medicinal purposes, contains potassium salts equivalent to 21.5% of potassium oxide in the leaves, to 38.0% in the stems, and to 28.6% in the roots (Warden, 1906). The elemental concentration of Na, Mg, P, S, Cl, K, Ca, Mn, Fe, Cu, Zn and Pb in the vegetative parts, leaves, stems and roots of the plant, have been reported (Ramamurthy *et al*., 2005). Quantitative analysis of the biosalts isolated from the plant are as follows: N^+ 0.92, K^+ 31.20, Ca^{2+} 1.41, SO_4^{2-} 18.48, OH^- 5.08, CO_3^{2-} 19.9, Cl^- 11.6, PO_4^{3-} 3.78 (Kadam *et al*., 2007). Among six common heavy metals *viz.* Pb, Zn, Cr., Fe, Ni and Cu analysed in the whole plant; Fe showed maximum concentration while Ni showed lowest concentration (Kumar *et al*., 2009a). Shendkar *et al*. (2011) reported the presence of 50 elements (5 macro elements, 27 trace elements and 18 heavy elements) in *Achyranthes aspera* stems in varying concentrations. Although the plant has been found to accumulate good quantity of Fe, K, Na and Mg, however, its trace heavy metal content is high according to the international safety standards for the consumption of human beings (Jabeen *et al*., 2010).

Chemical analysis of leaves and twigs of *Achyranthes aspera* collected from mineralized and non-mineralized areas in India, showed higher elemental concentrations in comparison with the non-mineralized area's plants (Biswas, 2007). A preliminary study on some herbal resources (including *Achyranthes aspera*) and their contamination with toxic heavy metals (Cd, Cr and Pb) around Pulicat Lake, north India, revealed relatively higher concentrations of Cd (4.81 μg mL^{-1}) and Cr (1.472 μg mL^{-1}) in plants when compared with soil samples (Kannan *et al*., 2007).

Assessment of *Achyranthes aspera* as an energy production source, revealed that the rate

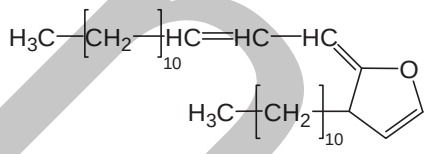
of gas production, in thermochemical conversion process was 2.212 m^3 kg^{-1}, and a biogass production of 20.131 kg^{-1}, in a biochemical conversion process (Subramanian and Sampathrajan, 1999).

Achyranthes aspera has been used as adsorbate for the adsorption of metal ions (Hussain *et al*., 2004). High concentration of Cr, Fe and Zn were observed in the roots, stems, leaves and seeds, while Pb was high only in the leaves (Hussain *et al*., 2006). A bioadsorbent was developed from *Achyranthes aspera* for removing methylene blue from waste water (Lohchab and Yadav, 2010).

Pharmacognostical studies on *Achyranthes aspera* have been reported (Prasad and Bhattacharya, 1961; Krishnaveni and Thaakur, 2006; Ou *et al*., 2011; Reddy *et al*., 2012).

Lipids and Volatlile Oil

The oil of *Achyranthes aspera* contains the following fatty acids: lauric, 0.4; myristic, 1.2; palmitic, 18.6; stearic, 4.4; arachidic, 1.6; behenic, 1.8; oleic 22.6; and linoleic, 49.4% (Daulatabad and Ankalgi, 1985). The major fatty acid of the seed oil (11.3 %) is oleic (55.4 %), followed by linoleic (25.0 %) and linolenic (12.8 %) acids. Palmitic, arachidic, eicosenic, behenic and erucic acids were present in minor amounts (Rashmi and Dayal, 2003). Also, the study of Chauhan *et al*. (2010) showed that the seed oil is rich in unsaturated fatty acids. A cyclic chain aliphatic compound (**42**) was isolated from the seeds (Chauhan *et al*., 2002).

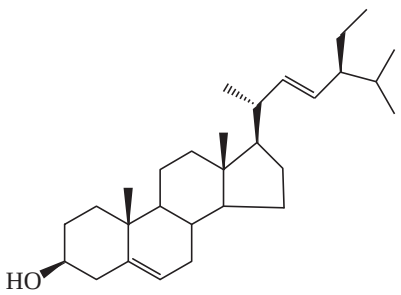


42

Rashmi and Dayal (2007) identified the following compounds from the volatile oil of the leaves of *Achyranthes aspera* growing in India: *p*-benzoquinone, hydroquinone, spathulenol, nerol, α-ionone, asarone and eugenol. Hydroquinone (57.7%) was found to be the chief constituent of the seven compounds which constitute 63.05% of the oil.

Steroids and Long Chain Compounds

Ecdysterone (**31**) (Banerji and Chadha, 1970; Banerji *et al*., 1971; Ikan *et al*., 1971) and 20-hydroxyecdysone (Kunert *et al*., 2000; Laddha and Ghosh, 2005), were identified from *Achyranthes aspera*. The presence of cardiac glycosides has been also reported (Arunkumar *et al*., 2010; Dey, 2011). β-Sitosterol (Misra *et al*., 1996), spinasterol (Ali *et al*., 2004) and stigmast-5,22-dien-3β-ol (**43**) (Sharma *et al*., 2009) were isolated from the plant.



43 Stigmast-5,22-dien-3β-ol

The following long chain compounds have been isolated from the different parts of the plant (roots, stems, shoots and seeds): pentatriacontane, 6-pentatriacontanone, hexatriacontane, tritriacontane, untriacontane (hentriacontane), 10-octacosanone, 10-triacosanone, 4-tritriacontanone, 36,47-dihydroxyhenpentacontan-4-one, tritriacontanol, 17-pentatriacontanol, 27-cyclohexylheptecosan-7-ol, 16-hydroxy-26-methylheptacosan-2-one, hentriacon-1-en-10-ol, tetracontanol-2, 4-triacontanone, 10-triacosanone, 4-methyl-heptatriacont-1-en-10-ol, *trans*-13-decasenoic acid, *n*-hexacosanoyl *n*-decaniate, *n*-hexacos-17-enoic acid, *n*-hexacos-11-enoic acid and *n*-hexacos-14-enoic acid (Gopalachari and Dhar, 1952; Batta and Rangaswami, 1973; Gariballa *et al*., 1983; Misra *et al*., 1991,1992,1993,1996; Ali, 1993; Dey, 2011; Srivastav *et al*., 2011).

Saponins

The saponins of *Achyranthes aspera* have been extensively studied. Gopalachari and Dhar (1952) reported that the seeds contain 2% saponins which gave on hydrolysis a sapogenin $C_{29}H_{46}O$ (m.p. 305^{o}C); having all the characteristic colours of steroids. The sugar moiety of the saponin was identified by paper chromatography as glucose. Later, they confirmed the presence of oleanolic acid as the aglycone and identified the sugars as galactose, glucose, rhamnose and xylose (Gopalachari and Dhar, 1958). Khastgir *et al*. (1958b) hydrolysed the alcoholic extract of the seeds and characterized the genin as oleanolic acid. The oleanolic acid content in the seeds was higher (0.970%) than that in the leaves (0.666%) (Mehta *et al*., 2010). The saponins identified from the different parts of *Achyranthes aspera* are shown in Table 9.

Nitrogenous and Phenolic Compounds

The plant has been reported to contain alkaloids (Basu *et al*., 1957a,b). The water-soluble base, $C_5H_{11}NO_2$, isolated from *Achyranthes aspera* was identified by Kapoor and Singh (1966) as simple betaine and not achyranthine $C_6H_{11}NO_2$, a betaine derivative of *N*-methylpyrrolidine-3-carboxylic acid, as reporterd by Basu *et al*. (1957). The crude alkaloid content (as achyanthine mg/100 g dry weight) of *Achyranthes aspera* was maximum in the shoots at the fruiting stage (0.874) and the flowering stage represented an intermediate position (Ratra, 1979). The presence of a simple betaine ($C_5H_{11}NO_2$) has been reported in the plant (Banerji *et al*., 1971; Mehta *et al*., 2011). Blunden *et al*. (1999) stated that the plant contains glyinebetaine (0.43% dry weight). The presence of alkaloids has been also reported by others (e.g. Basu 1957; Neogi *et al*., 1970). 3-Acetoxy-6-benzoyloxyapangamide (**52**) has been isolated from the stem (Abdul Aziz *et al*., 2005).

Quercetin 3-*O*-β-D-galactoside and quercetin were detected in the aerial parts of the plant (Kunert *et al*., 2000; Tullanithi *et al*., 2010). Phytochemical investigation of *Achyranthes aspera* revealed the presence of tannins (Sutar *et al*., 2008; Manjula *et al*., 2009).