Proximate Composition, Carbohydrates and Proteins

The proximate composition of *Amaranthus tricolor* is shown in Table 59

Table 59. Proximate composition of *Amaranthus tricolor*

Plant part	Protein %	Carbohydrates %	Fat %	Ash %
Leaves[1]	6.10	9.75		
Leaves[2]	3.49		0.15	2.12
Seeds[3]	11.70-12.90			

1.Srivastava (2011); 2. Schönfeldt and Pretorius (2011); 3. Srivastave and Roy (2012).

The mineral content of the leaves of *Amaranthus tricolor* is Na, 34.00±1.23; K, 39.00±1.01; Ca, 20.00±0.56; Fe, 10.00±0.78 mg/100g (Srivastava, 2011). However, the concentrations of minerals in leaves, reported by Schönfeldt and Pretorius (2011) are: Fe, 16.2; Zn, 0.8; Mg, 141; Ca, 232 and P, 70.6 mg/100g. *Amaranthus mangostanus* L. contains plentiful mineral elements especially Ca, K, and Mg which imply that the nutritive value is high (Sun *et al.*, 2010). There are several reports on the nutritional ingredients and health functions of *Amaranthus mangostanus* (e.g. Sun *et al.*, 2010; Zhao, 2010b), *Amaranthus gangeticus* (e.g. Kamath and Sohonie, 1956; Yadav and Sehgal, 1999) and *Amaranthus tricolor* (e.g. Punia *et al.*, 2004; Singh *et al.*, 2009b; Shukla *et al.*, 2010; Patil *et al.*, 2012). Fruit vinegar beverage prepared from *Amaranthus mangostanus* and other plant species has been described (Wang, 2012). *Amaranthus tricolor* accumulates Cd and can be useful for phytoremediation of Cd-contaminated soils (Fan and Zhou, 2009; Watanabe *et al.*, 2009; Al-Rmalli *et al.*, 2012). Bioaccumulation of Mn, K, Br, Sr and Mo by the plant was reported (Gorelova *et al.*, 2009).

The protein, fat, total minerals, crude fiber, carbohydrates and energy content of raw leaves of *Amaranthus tricolor* and *Digera arvensis* varied from 27.89 to 28.44, 1.74 to 4.55, 20.26 to 22.61, 5.50 to 8.00, 38.90 to 42.11 g and 294.64 to 310.31 kCal/100 g, dry wt. respectively, Ca, Fe, ascorbic acid and β-carotene content of the raw leaves were 3135.0 to 3289.58, 3.35 to 8.98, 104.34 to 170.39 mg/100 g and 13464 to 14057 µg/100 g, dry weight respectively. It was concluded that these leaves and their products are good sources of protein, Ca, Fe, and β-carotene (Punia *et al.*, 2004).

The following amino acids were identified in *Amaranthus tricolor*: proline, cysteine, tryptophan, phenylalanine, serine, glutamic acid, arginine and leucine (Behari and Sharma, 1984). Consistent changes in the free amino concentrations in response to Na nutrition were observed in *Amaranthus tricolor*. Alanine, γ-aminobutyric acid, and glycine were present in greater and aspartate and arginine in lower concentrations in mature leaves of Na-deficient than in normal plants (Grof *et al.*, 1986).

The amino acid content and Van Slyke nitrogen distribution of *Amaranthus gangeticus* was reported. The protein preparation was found to contain about 3 times as much arginine as is found in casein. The basic-N fraction was 38.4 % of the total nitrogen. The nutritionally limiting amino acid is lysine (Kamath and Sohonie, 1956). Amino acid contents, rate of release of soluble N and essential amino acids, and proximate composition of *Amaranthus gangeticus* were determined. The vegetable was reported inferior to casein, at 8 % protein level, in biological value, digestibility, N utilization, and liver protein regenerating ability and was approximately equal to casein in regeneration of serum protein, red blood cells, hemoglobin and xanthin oxidation. As the rate of lysine release from the plant is high, it is

suggested that the vegetable may be valuable in supplementing lysine-deficient diets, such as those where cereals are used exclusively (Kamath and Sohonie, 1959). Deshpande and Rao (1954) reported that about 37 % of the N amaranth (*Amaranthus gangeticus*) leaves can be extracted by water, 36 % by 5 % NaCl, 24 % by 70 % EtOH, and 48 % by 0.1 % NaOH. The purification and characterization of the antiviral protein (AAP29) from the leaves of *Amaranthus mangostanus* have been described (Cho *et al*., 1995).

The availability of Ca in some leafy vegetables, including *Amaranthus gangeticus*, has been reported (Basu and Ghosh, 1943). *Amaranthus gangeticus* has a high Ca content (0.54 %). In spite of a fairly high oxalic acid content, its Ca was as well utilized as milk (Devadatta and Appanna, 1954). Oxalic acid has been reported as a normal major constituent of green leaves of *Amaranthus gangeticus* (Srivastava and Krishnan, 1959). In comparison with the utilization of the Fe in $FeCl_3$, the percentage of total Fe available in the same species was found 32 (Miller and Louis, 1945). However, Shah and Patel (1955) reported that the total iron and available iron in the plant are 10.0 and 2.0 mg/100 g of vegetable.

Amaranthus tricolor contains large amounts of vitamin C, and there is a relationship between the amounts of vitamin C and cholorophyll (Mitsuda, 1938,1949). The ascorbic acid content of *Amaranthus gangeticus* was highest when the plant was harvested after 29 days. Leaves then had 155 mg/100 g, the stem 32 mg/100 g. The loss of ascorbic acid increased with storage time and higher storage temperature (Devadas *et al*., 1965). The bioavailability of thiamin, riboflavin and niacin from commonly consumed green vegetables (including *Amaranthus gangeticus*) in the rural areas in India has been studied (Girija *et al*., 1982). The leaves are a rich source of ascorbic acid and β-carotene (Yadav and Sehgal, 1999).

Glucose and fructose were identified in *Amaranthus tricolor* starch (Behari and Sharma, 1984). The plant had a mean amylose content of 29.0 % (Wu and Corke, 1999). A water-soluble polysaccharide, isolated from the stems of *Amaranthus tricolor* Linn. (*Amaranthus gangeticus* L.), was found to consist of L-arabinose, methyl-D-galacturonate, D-galactose, and 3-*O*-Ac-L-rhamnose in a molar ratio of nearly 1:1:1:1 (Sarkar *et al.*, 2009).

Pharmacognostic characterstics of the plant have been described (Rao *et al.*, 2010b, Tharun *et al.*, 2012).

Lipids and Volatile Oil

The major saturated fatty acid in seeds, stems, and leaves of *Amaranthus tricolor* was palmitic acid. The major unsaturated fatty acid in seeds and stems was linoleic acid, whereas in leaves it was linolenic acid. Linolenic, lignoceric and arachidic acids were also present in seeds, but in trace amounts (Fernando and Bean, 1984). The lipid fraction of the plant contains a series of C_{25} - C_{35} alkanes, a series of C_{24} - C_{32} aliphatic alcohols and sterols which include sitosterol, stigmasterol, campesterol, cholesterol, 24-methylenecholesterol, fucosterol, isofucosterol (Behari and Sharma, 1984) and spinasterol (Fernando and Bean, 1984). Among the seeds, stems, and leaves, a small amount of 24-methylenecycloartenol was found in the seeds only (Fernando and Bean, 1984). Other sterols isolated from *Amaranthus gangeticus* and *Amaranthus tricolor* are shown in Tables 34, 56 and 60 (Fernando and Bean, 1985; Xu *et al*., 1986; Patterson *et al*., 1991). Chernenko *et al*. (1999) stated that α-spinasterol predominates and reaches 52% in *Amaranthus tricolor*.

The seeds of *Amaranthus gangeticus* contain 6% oil (Chidambaram and Iyer (1945). The composition of the fatty acids of the seed oil (4.17 %) were reported by Chowdhury and Bagachi (1956) as follows: linolenic, nil; linoleic, 37.53; oleic, 56.18 and saturated, 6.29 %. However, Badami and Patil (1976) stated that the seed oil contained myristic, 0.5; palmitic, 22.1; stearic, 8.6; arachidic, 2.6; behenic, 1.8; oleic, 39.1; and linoleic, 25.2 %. *Amaranthus gangeticus* leaves yielded, on extraction with chloroform-methanol 10.6 % lipids (dry

Table 60. The sterols of *Amaranthus tricolor* leaves*

Sterol	% of total sterol
1. Cholesterol	2.6
2. 7,22- Ergostadienol	3.0
3. Campesterol	1.1
4. Stigmasterol	3.8
5. 7,24(28)-Ergostadienol	4.3
6. 7-Ergostenol	11.2
7. Spinasterol	52.4
8. Sitgmastanol	2.6
9. Stigmastenol	2.1
10. 7,25-Stigmastadienol	2.1
11. 7-Stigmastenol	8.6
12. 7,24(28)-Stigmastadienol	4.8
13. 24-Methylenecycloartanol	1.3

* Xu *et al*. (1986).

weight) which were separated into nonpolar lipids (53.6 %), glycolipids (33.8 %), and phospholipids (12.6 %) (Lakshminarayana *et al*., 1984). The nonpolar lipids were made up (wt. %) of pigments (8.1), hydrocarbons (4.9), ester waxes (1.8), fatty acid methyl esters (2.7), triacylglycerols (6.4), fatty acids (5.6), diacylglycerols (5.6), sterols (9.3), monoacylglycerols (4.7), and unidentified components (4.5). The glycolipids comprised (wt. %) monogalactosyl diglycerides (15.6), steryl glycosides (4.1), cerebrosides (6.8) and digalactosyl diglycerides (7.3). The phospholipids consisted (wt. %) of cardiolipin (2.0), phosphatidylglycerol (3.1), phosphatidylethanolamine (3.2), phosphatidylinositol (1.7), and phosphatidylcholine (2.6). The usual fatty acids were found in varying concentrations in different lipid classes. *trans*-3-Hexadecenoic acid amounted to 12.3 % in phosphatidylglycerol fatty acids (Lakashminarayana *et al*., 1984). Phosphatidylserine was also reported in the polar lipids by Lorenz and Hwang (1985). Three galactosyl diacylglycerols were isolated from leaves and stems of *Amaranthus tricolor viz*. 1,2-dilinolenoyl-3-galactosyl glycerol, 1-linolenoyl-2-palmitoyl-3-galactosyl glycerol and 1-linolenoyl-2-steroyl-3-galactosyl glycerol (Jayaprakasam *et al*., 2004).

Fifty-six components (including 15 alcohols, 5 esters, 13 aldehydes, 8 keones, 3 hydrocarbons, 9 acids and 5 miscellaneous) were identified in the essential oil of *Amaranthus mangostanus* (Kim and Lee, 1988).

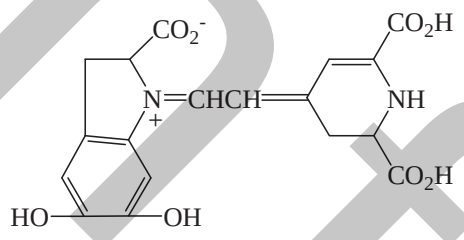
Other Constituents

Rutin was isolated from the whole plant of *Amaranthus mangostanus* (Kim, 2000). Both rutin and quercetin were detected by Kalinova and Dadakova (2009). The total polyphenolic content and antioxidant activity were compared in the leaves of seven red amaranth (*Amaranthus tricolor*) cultivars (Khandakar *et al*., 2008). The total phenolic content and antioxidant activity differed among the cultivars studied, and leaves from the cultivar 'Rocto Joba' and 'Rocto Lal' had the highest phenolics and antioxidant activity, respectively. The positive correlation between antioxidant activity and total polyphenols suggests that phenolic

compounds are the major antioxidant components in red amaranth. The results indicate that red amaranth containing high phenolics may provide a source of dietary antioxidants (Khandakar *et al*., 2008). Red pigments were isolated from the plant (Huo and Guo, 1996; Zhang, 2001).

The following carotenoids have been identified from *Amaranthus tricolor*: β-carotene, zeaxanthin, lutein, antheraxanthin, flavoxanthin, auroxanthin, luteoxanthin, violaxanthin, neoxanthin, neoxanthin a, and neoxanthin b (Wills and Rangga, 1996).

The isolation of amaranthine and isoamaranthine is reported from the leaves of *Amaranthus tricolor* (Piattelli *et al*., 1964) and leaves and petioles of *Amaranthus gangeticus* (Zakharova *et al*., 1995). Amaranthine and isoamaranthine are *O*-(β-D-glucopyranosyluronic acid)-5-*O*-β-D-glucopyranosides of betanidine (**93**) and isobetanidine respectively (Piatelli *et al*., 1964). Also, Huang and von Elbe (1986) extracted amaranthine from leaves and described its stability. The study of this red pigment in *Amaranthus tricolor* has been reported by others (e.g. Shen and Hwang, 1985; Chen, 1992, 1993; Cai *et al*., 1998a). The pigment distribution and harvest time of the different parts of *Amaranthus tricolor* are shown in Table 36 (Cai *et al*., 1998a). Glycinebetaine and trigonelline were identified in *Amaranthus mangostanus* (Table 35) (Blunden *et al*., 1999). *Amaranthus tricolor* contains 2.89 % saponins (Ateya, 1992).



93 Betanidine

Biosynthesis

It has been shown (De Nicola *et al*., 1972a,b) that light acts on betacyanin (amaranthin) biosynthesis in *Amaranthus tricolor* through the control of the availability of energy-rich compounds; phytochrome and photosynthetic system are involved in this regulation in conditions of short- and long-term irradiation respectively, while gene activation seems to be mediated by other photoreceptor(s) than phytochrome. In complete darkness amaranthin synthesis is stimulated by kinetin, whose action appears not to be related to the status of phytochrome (De Nicola *et al*., 1973). From the results obtained by De Nicola *et al*. (1973), it is apparent that there are marked qualitative similarities between the light responses of betaxanthin and betacyanin synthesis. The light-induced synthesis of amaranthin in *Amaranthus tricolor* seedlings at 0-48 hours postgermination was inhibited by chloramphenicol. The inhibition was similar to that previously found using puromycin. The inhibitory effect of both antibiotics decreased with the seedling age (Piattelli *et al*., 1970). The composition and content of secondary compounds produced by the shikimate pathway and the contents of protein and cellulose were determined in the leaves of amaranth *(Amaranthus tricolor*) K-99 and the cultivar Valentina raised from it by family selection and enriched in the pigment amaranthine (Gins *et al*., 2002). It was found that intense biosynthesis of amaranthine, tyrosine, and phenylalanine resulted in a decrease in the contents of lignin, protein and cellulose. The latter authors concluded that amaranth