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# Composition of Indian Aquatic Plants in Relation to Utilization as Animal Forage

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## ABSTRACT

Dry matter values of thirty species of aquatic plants ranged from 4 to 16%, with twenty nine species having more than 10% crude protein. Aquatic plants had lower fibre and higher fat and ash contents when compared to dry terrestrial roughages commonly used as animal feed. Eighteen plants had ash values below 15%. Alkaloids, nitrates and polyphenol contents were determined. When compared to conventional animal forages, twelve aquatic plants appear to have potential for utilization as a forage.


*Key words*: Chemical composition, minerals, alkaloids, nitrates, polyphenols.

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## INTRODUCTION

Aquatic plants grow profusely in lakes and waterways all over the world and have in recent decades their negative effects magnified by man's intensive use of natural water bodies. Eradication of the weeds has proved almost impossible and even reasonable control is difficult. Turning these weeds to productive use would be desirable if it would partly offset the costs involved in mechanical removal. Among other uses, there has been considerable interest in using aquatic plants as a source of animal feed (2).

Since aquatic weeds are known to differ widely in their chemical composition depending upon species, season and location (2), an insight into their chemical composition is essential if utilization prospects are to be considered. The purpose of this study was to supplement existing knowledge on aquatic plants by evaluating the chemical and min-

eral composition of plants found in this agro-climatic region and to examine their suitability as a feed source. These plants were also tested for the presence of some anti-nutritive factors, the presence of which could limit utilization prospects.

## MATERIALS AND METHODS

Samples of thirty aquatic weeds (Table 1) were selected according to their availability and collected from sites in and around Calcutta. Identification of plant samples whenever necessary, was done at the National Herbarium, Indian Botanical Gardens, Sibpur, Howrah. The plants were harvested in a lush, green condition from different areas within each stand to form three representative samples for each species. The harvested materials were placed in polyethylene bags and transported to the laboratory where they were cut to include only leaves and shoots. These were then washed thoroughly and additional moisture drained before being weighed and dried in an oven at 100C to constant weight for dry matter determinations. A part of each plant sample was dried separately at 50C to constant weight for estimation of anti-nutritive factors. All samples were ground in a mill and stored until analyses could be conducted.

TABLE 1. AQUATIC PLANTS WITH SCIENTIFIC, COMMON NAMES AND MONTH OF COLLECTION THAT WERE COLLECTED NEAR CALCUTTA, INDIA FOR NUTRIENT AND FORAGE FEED EVALUATIONS

| Scientific Name | Common Name | Month of collection |
|---|---|---|
| *Allmania nodiflora* R. Br. | — | July |
| *Alternanthera philoxeroides* | Alligator weed | August |
| *Azolla pinnata* R. Br. | Water velvet | September |
| *Ceratophyllum demersum* L. | Horn wort | October |
| *Commelina benghalensis* L. | Day flower | August |
| *Eichhornia crassipes* (Mart.) Solms. | Water hyacinth | October |
| *Enhydra fluctuans* Lour. | Watercress | September |
| *Gentiana lutea* | — | September |
| *Hydrilla verticillata* (L.) Royle | Hydrilla | August |
| *Hydrocotyle asiatica* L. | Penny wort | September |
| *Hygrophila spinosa* | — | August |
| *Ipomoea reptans* Poir. | Water spinach | September |
| *Jussiaea repens* L. | — | March |
| *Lemna minor* L. | Duckweed | August |
| *Limnanthemum cristatum* (Roxb.) Griseb. | Snowflake | July |
| *Limnophila heterophylla* | — | September |
| *Lippia geminata* | — | August |
| *Marsilea quadrifolia* L. Willd | — | March |
| *Mikania scandens* Willd | Climbing hempweed[1] | August |
| *Nelumbo nucifera* Gaertn. | Lotus | July |
| *Nymphaea nouchali* Burm. f. | Red waterlily | July |
| *Nymphaea stellata* Willd | Blue waterlily | July |
| *Ottelia alismoides* (L.) Pers. | — | September |
| *Pistia stratiotes* L. | Water lettuce | August |
| *Phragmites karka* (Retz.) Trin. ex. Stued. | Giant reed | September |
| *Polygonum barbatum* L. | Knot weed | August |
| *Salvinia auriculata* Aubl. | Water fern | July |
| *Trapa bispinosa* Roxb. | Water chestnut | October |
| *Typha elephantina* Roxb. | Cattails | October |
| *Vallisneria spiralis* L. | Tapegrass | March |

[1]*Mikania scandens* is basically a terrestrial weed but the sample used here grew profusely in damp ditches and on the margins of ponds.

Nitrogen (N), crude fat, crude fibre and ash were estimated using standard methods (3). Crude protein was calculated as percent N times 6.25. Nitrogen free extractives (NFE) comprising the sugars, starches and a large part of the material classed as hemicellulose was determined by difference (14). For mineral analyses ash samples were dissolved in nitric acid ($HNO_3$, 50% v/v) and diluted with double distilled water (1:10). The acid digest was used for the estimation of phosphorus (P) (7). Sodium (Na), potassium (K) and calcium (Ca) were estimated by flame photometry. Among anti-nutritive factors alkaloids (9), nitrates (8) and polyphenols (20) were estimated. In case of polyphenols, the free and bound forms were extracted separately (17) and then analysed.

To test differences between the various plants, the data on chemical and mineral composition were subjected to analysis of variance (18). When significance was observed at 5% level, the least significant difference (L.S.D.) for the same significance level was determined.

## RESULTS AND DISCUSSION

The proximate analyses of the thirty species of aquatic plants studied are reported in Table 2. Among the nine plants found to contain more than 10% dry matter, seven were emergent hydrophytes and two were floating types. Emergent plants have been previously reported to contain more dry matter than submersed plants (6). All submersed plants had dry matter values below 7% while the same was true for eight floating varieties (including the blue water lily). All species contained more than 10% crude protein, except cattails which had a value of 8.7%. N concentration of floating leaved and submersed species have been reported to be higher than those of emergent plants (16). However, in this study, crude protein values of emergent plants were comparable to those of floating ones. Variations in protein levels are probably due to environmental differences since nutrient concentrations in the aquatic environment are known to affect crude protein content of water plants (10). Thirteen species had crude fat values above 4% while all submersed plants had values below 4%. Hydrilla had a fat content of 3.7% while there was no significant difference between the fat contents of the other submersed species. Aquatic plants have been reported to contain 1.18 to 5.42% crude fat (6).

Fibre contents ranged from 15.1% in hydrilla to 28.1% in cattails. Most floating and emergent types had more fibre content than the submersed plants. This was probably because they require more strength to support aerial vegetation. No significant differences exist between the fibre contents (above 25%) of tall weeds like cattails and giant reed. These could be used as potential substitutes for hay and other roughages eaten by ruminant animals. Crude fibre values for some aquatic plants were lower than those reported in literature (6). This was probably because all harvests conducted here were primarily on lush, green vegetation. The NFE of the aquatic plants varied from 32.8% in the climbing hempweed to 50.2% in cattails. If water plants are to be used as animal feeds, NFE is a practically useful index of the non-cellulose portion of feed carbohydrates and is primarily a non-specific source of

TABLE 2. PROXIMATE COMPOSITION (% OF DRY WEIGHT) OF AQUATIC PLANTS COLLECTED NEAR CALCUTTA, INDIA FOR LABORATORY EVALUATION AS FORAGES

| Plant | Dry matter (%) | Crude protein | Ash | Crude fat | Crude fibre | Nitrogen free extract |
|---|---|---|---|---|---|---|
| FLOATING | | | | | | |
| *Azolla pinnata* | 6.6 | 21.9 | 15.4 | 3.8 | 16.6 | 42.3 |
| *Eichhornia crassipes* | 8.4 | 14.5 | 13.2 | 4.3 | 20.8 | 47.2 |
| *Gentiana lutea* | 9.1 | 17.2 | 12.9 | 2.2 | 22.7 | 45.0 |
| *Ipomoea reptans* | 4.9 | 20.6 | 16.5 | 4.6 | 27.0 | 31.3 |
| *Jussiaea repens* | 5.0 | 18.1 | 12.4 | 3.9 | 25.5 | 40.1 |
| *Lemna minor* | 6.0 | 20.4 | 17.2 | 3.8 | 15.7 | 42.9 |
| *Limnanthemum cristatum* | 5.9 | 24.4 | 14.5 | 2.2 | 22.4 | 36.5 |
| *Nelumbo nucifera* | 10.3 | 21.9 | 9.9 | 2.8 | 23.7 | 41.7 |
| *Nymphaea nouchali* | 8.4 | 16.8 | 18.7 | 2.8 | 26.3 | 35.4 |
| *Nymphaea stellata* | 7.0 | 16.7 | 14.1 | 2.6 | 24.0 | 42.6 |
| *Pistia stratiotes* | 5.3 | 20.5 | 17.0 | 3.8 | 19.1 | 39.6 |
| *Salvinia auriculata* | 4.6 | 14.6 | 12.5 | 2.9 | 25.0 | 45.0 |
| *Trapa bispinosa* | 10.6 | 10.8 | 13.6 | 5.1 | 27.7 | 42.8 |
| SUBMERSED | | | | | | |
| *Ceratophyllum demersum* | 6.9 | 15.8 | 25.3 | 3.0 | 20.7 | 35.2 |
| *Hydrilla verticillata* | 5.9 | 16.6 | 20.4 | 3.7 | 15.1 | 44.2 |
| *Ottellia alismoides* | 4.1 | 14.3 | 16.5 | 2.9 | 20.5 | 45.8 |
| *Vallisneria spiralis* | 6.8 | 17.6 | 22.6 | 3.1 | 16.4 | 40.3 |
| EMERGENT | | | | | | |
| *Allmania nodiflora* | 10.8 | 22.6 | 14.7 | 4.9 | 22.3 | 35.5 |
| *Alternanthera philoxeroides* | 9.9 | 25.9 | 10.5 | 4.7 | 22.3 | 36.6 |
| *Commelina benghalensis* | 6.0 | 16.9 | 20.2 | 4.9 | 23.4 | 34.6 |
| *Enhydra fluctuans* | 5.9 | 19.7 | 16.8 | 4.3 | 22.9 | 36.3 |
| *Hygrophila spinosa* | 10.3 | 20.6 | 18.3 | 3.4 | 21.3 | 36.4 |
| *Hydrocotyle asiatica* | 7.3 | 12.3 | 17.9 | 4.1 | 27.6 | 38.1 |
| *Limnophila heterophylla* | 10.3 | 15.4 | 12.6 | 4.3 | 23.3 | 44.4 |
| *Lippia geminata* | 10.7 | 19.1 | 18.3 | 3.8 | 24.6 | 34.2 |
| *Marsilea quadrifolia* | 8.1 | 16.8 | 19.5 | 4.6 | 23.4 | 35.7 |
| *Mikania scandens* | 7.4 | 22.5 | 17.7 | 4.5 | 22.5 | 32.8 |
| *Phragmites karka* | 15.9 | 13.2 | 9.4 | 4.2 | 26.4 | 46.8 |
| *Polygonum barbatum* | 14.5 | 26.8 | 8.0 | 4.6 | 22.0 | 38.6 |
| *Typha latifolia* | 14.4 | 8.7 | 9.5 | 3.5 | 28.1 | 50.2 |
| L.S.D. (5%) | 0.8 | 1.5 | 1.1 | 0.6 | 1.3 | — |

energy to the animals. The NFE of commonly used green roughages varied from 36.6% in lucerne to 51.6% in maize (4).

Ash values ranged from 8.0% in knotweed to 25.3% in hornwort, submersed plants having significantly higher amounts of ash probably due to extraneous mineral deposition which often occurs in these plants. Although adequate levels of essential mineral nutrients are an important aspect of nutritive quality, excessive concentration of ash decreases the amount of organic constituents per unit weight and lowers food value (16). However, ash values below 15% were observed in eight floating and six emergent plants. In some green roughages commonly used as livestock feed, ash content ranged from 8.6% in maize to 14.2% in cowpea (4).

The ash content is of little value in evaluating the nutritive value of a feed since it is the individual elements that are important in the metabolic processes. Rations deficient in calcium and phosphorus can lead to serious fertility problems whereas sodium deficiency results in retarded growth (19). The mineral content of the aquatic plants were, therefore, studied and are reported in Table 3. The giant reed had the lowest Na content of 0.31% while the highest of 2.86% was in the snowflake. Nine floating, four emergent and three submersed plants had more than 1% Na which is relatively high when compared to levels present in terrestrial plants (10). Na levels were generally higher in submersed and floating plants than in emergent ones. K concentrations in the plants studied were found to be higher than reported values (12). Five emergent, three floating and two submersed plants had K contents of more than 3% while all submersed plants had values more than 2.5%. Only five plants had Ca contents above 1% with hydrilla having significantly the highest. The P content varied from 0.13% in giant reed and cattails to 0.83% in water cress. All plants had P values below 1%, the submersed hydrophytes having values less than 0.35%. On an average, the P content of aquatic plants was higher than that of forage crops (4). The tissue chemistry of aquatic plants has been reported to show considerable variation in mineral composition which may be attributed to the age and type of plants sampled, and the fertility of the aqueous environment (10). When plants are to be considered for use as a feed source the calcium : phosphorous ratio constitutes an important parameter. This ratio should be within the range of 0.5 to 2.0 for the healthy growth of animals and should not be more than 6.0 (15). Excepting cattails, all plants had values below 5.0 while seventeen plants had a Ca/P ratio between 0.5 and 2.0.

If aquatic vegetation is to be used as feed material,

TABLE 3. SELECTED MINERAL CONTENT (% OF DRY WEIGHT) OF AQUATIC PLANTS COLLECTED NEAR CALCUTTA, INDIA

| Plant | Sodium (Na) | Potassium (K) | Calcium (Ca) | Phosphorus (P) | Ca/P ratio |
|---|---|---|---|---|---|
| FLOATING | | | | | |
| *Azolla pinnata* | 0.83 | 0.75 | 0.45 | 0.33 | 1.36 |
| *Eichhornia crassipes* | 0.53 | 3.68 | 1.04 | 0.37 | 2.81 |
| *Gentiana lutea* | 1.06 | 1.92 | 0.46 | 0.26 | 1.76 |
| *Ipomoea reptans* | 1.39 | 3.29 | 0.59 | 0.48 | 1.23 |
| *Jussiaea repens* | 1.01 | 1.77 | 0.36 | 0.45 | 0.80 |
| *Lemna minor* | 1.99 | 2.38 | 1.10 | 0.48 | 2.29 |
| *Limnanthemum cristatum* | 2.86 | 2.65 | 0.54 | 0.14 | 3.86 |
| *Nelumbo nucifera* | 1.10 | 1.92 | 0.33 | 0.36 | 0.92 |
| *Nymphaea nouchali* | 1.19 | 2.23 | 0.52 | 0.32 | 1.63 |
| *Nymphaea stellata* | 0.93 | 1.30 | 0.95 | 0.21 | 4.52 |
| *Pistia stratiotes* | 1.41 | 3.26 | 0.48 | 0.64 | 0.75 |
| *Salvinia auriculata* | 1.01 | 0.83 | 0.27 | 0.19 | 1.42 |
| *Trapa bisponosa* | 0.61 | 0.26 | 0.47 | 0.15 | 3.13 |
| SUBMERSED | | | | | |
| *Ceratophyllum demersum* | 1.06 | 3.40 | 0.65 | 0.29 | 2.24 |
| *Hydrilla verticillata* | 0.75 | 2.56 | 1.35 | 0.28 | 4.82 |
| *Ottelia alismoides* | 1.92 | 3.74 | 0.60 | 0.19 | 3.16 |
| *Vallisneria spiralis* | 2.06 | 2.72 | 0.49 | 0.32 | 1.53 |
| EMERGENT | | | | | |
| *Allmania nodiflora* | 0.60 | 3.89 | 0.64 | 0.35 | 1.83 |
| *Alternanthera philoxeroides* | 0.76 | 2.33 | 0.42 | 0.26 | 1.62 |
| *Commelina benghalensis* | 0.98 | 2.70 | 0.40 | 0.36 | 1.11 |
| *Enhydra fluctuans* | 1.21 | 2.97 | 0.45 | 0.83 | 0.54 |
| *Hygrophila spinosa* | 1.39 | 4.83 | 0.81 | 0.40 | 2.03 |
| *Hydrocotyle asiatica* | 1.40 | 3.22 | 0.50 | 0.32 | 1.56 |
| *Limnophila heterophylla* | 0.83 | 0.95 | 1.17 | 0.31 | 3.77 |
| *Lippia geminata* | 0.79 | 3.37 | 1.15 | 0.51 | 2.25 |
| *Marsilea quadrifolia* | 0.55 | 1.74 | 0.44 | 0.34 | 1.29 |
| *Mikania scandens* | 1.40 | 3.06 | 0.48 | 0.39 | 1.23 |
| *Phragmites karka* | 0.31 | 1.55 | 0.28 | 0.13 | 2.15 |
| *Polygonum barbatum* | 0.52 | 1.10 | 0.37 | 0.33 | 1.12 |
| *Typha latifolia* | 0.44 | 1.65 | 0.78 | 0.13 | 6.00 |
| L.S.D. (5%) | 0.10 | 0.11 | 0.10 | 0.06 | — |

some attention should also be given to factors affecting the quality of the plant material. Many plants contain a wide variety of natural chemical compounds often referred to as anti-nutritive substances or toxic factors which are capable of inducing toxic effects in animals consuming these plants (5). Some of these toxic factors were studied in the thirty plants and the results are reported in Table 4. Alkaloids present in certain plants, many of them having poisoning properties, comprise the largest single class of secondary plant substances. Their qualitative presence was tested in each plant sample subjected to differential extraction (9). Their complete absence was noted in both fractions of twenty plants while their presence was detected in five plants, alligator weed, climbing hempweed, giant reed, knot weed and lotus.

Nitrate content varied from 0.76% in lotus to 1.83% in *Hygrophila spinosa*. Nitrates are known to accumulate in forage plants and in some weeds at levels high enough to be toxic to animals (21). A nitrate content of less than 1.5% has been considered to be safe for use as animal feed (5). Five emergent weeds (dayflower, climbing hempweed, knotweed, cattails and *Hygrophila spinosa*), one submersed (tapegrass) and one floating (red water lily) hydrophyte had nitrate levels above 1.5% which could prove to be harmful.

The phenolic contents of the plants were studied in view of the adverse effect of these compounds on growth due to their interference with protein digestibility (5). Seventeen of the thirty species had a total polyphenolic content below 5% while *Jussiaea repens, Ottelia alismoides* and *Nymphaea stellata* exhibited values above 10%. Plants having a tannin content of 6% and above have been reported to be low in digestibility (13) and hence of little feed value. Bound polyphenols present in plants are known to inhibit the rate of attack by proteolytic enzymes thereby resulting in a low *in vitro* digestibility (11). Among thirty plants tested, free phenolic content was found to be more than the bound ones in twenty-three plants.

Comparing the composition of aquatic plants with those of conventionally used livestock feed (4), aquatics on an average, contained larger amounts of crude protein. Six floating and five emergent species had more than 20% crude protein. Among the six floating varieties, the snowflake had the highest (24.4%) protein, while there was no significant difference in the protein contents of duckweed, water lettuce, water spinach, azolla and lotus. Since roughages such as straws which form the staple feed for most of the Indian livestock contain less than 4 to 5% protein, an additional source of protein is generally needed with straw diets (1). Aquatic plants could, there-

TABLE 4. POTENTIAL TOXIC COMPOUNDS (% OF DRY WEIGHT) FOUND IN AQUATIC PLANTS COLLECTED NEAR CALCUTTA, INDIA

| Plant | Alkaloids[1] Fraction A | Alkaloids[1] Fraction B | Nitrates | Polyphenols Total | Polyphenols Free | Polyphenols Bound |
|---|---|---|---|---|---|---|
| FLOATING | | | | | | |
| *Azolla pinnata* | – | – | 1.3 | 5.2 | 1.4 | 3.7 |
| *Eichhornia crassipes* | – | – | 0.8 | 4.1 | 1.1 | 3.0 |
| *Gentiana lutea* | – | – | 1.2 | 6.0 | 4.6 | 1.5 |
| *Ipomoea reptans* | – | – | 1.4 | 3.7 | 2.8 | 0.9 |
| *Jussiaea repens* | – | – | 0.6 | 16.1 | 14.8 | 1.3 |
| *Lemna minor* | – | – | 0.8 | 7.2 | 1.1 | 6.1 |
| *Limnanthemum cristatum* | – | – | 1.0 | 3.2 | 2.9 | 0.3 |
| *Nelumbo nucifera* | + | + | 0.8 | 4.5 | 3.3 | 1.2 |
| *Nymphaea nouchali* | + | – | 2.0 | 8.7 | 5.9 | 2.8 |
| *Nymphaea stellata* | + | – | 0.9 | 10.2 | 9.3 | 0.9 |
| *Pistia stratiotes* | – | – | 1.3 | 2.2 | 1.6 | 0.6 |
| *Salvinia auriculata* | – | – | 1.1 | 2.0 | 1.2 | 0.8 |
| *Trapa bispinosa* | – | – | 1.2 | 7.0 | 5.8 | 1.2 |
| SUBMERSED | | | | | | |
| *Ceratophyllum demersum* | – | – | 1.4 | 0.9 | 0.8 | 0.2 |
| *Hydrilla verticillata* | – | – | 1.2 | 1.0 | 0.8 | 0.3 |
| *Otellia alismoides* | – | – | 1.0 | 11.4 | 7.4 | 4.0 |
| *Vallisneria spiralis* | – | – | 1.5 | 1.3 | 1.2 | 0.2 |
| EMERGENT | | | | | | |
| *Allmania nodiflora* | – | – | 1.2 | 2.9 | 1.7 | 1.1 |
| *Alternanthera philoxeroides* | + | + | 1.5 | 6.7 | 1.9 | 4.8 |
| *Commelina benghalensis* | – | – | 1.8 | 3.4 | 2.1 | 1.3 |
| *Enhydra fluctuans* | + | – | 1.4 | 5.0 | 3.8 | 1.2 |
| *Hygrophila spinosa* | – | – | 1.8 | 5.9 | 1.2 | 4.8 |
| *Hydrocotyle asiatica* | – | + | 1.5 | 4.0 | 3.5 | 0.5 |
| *Limnophila heterophylla* | – | – | 0.8 | 3.6 | 1.3 | 2.3 |
| *Lippia geminata* | – | – | 1.3 | 5.2 | 2.8 | 2.4 |
| *Marsilea quadrifolia* | + | – | 1.3 | 3.3 | 2.7 | 0.6 |
| *Mikania scandens* | + | + | 1.6 | 2.9 | 1.6 | 1.3 |
| *Phragmites karka* | + | + | 1.5 | 5.2 | 3.0 | 2.2 |
| *Polygonum barbatum* | + | + | 1.5 | 6.9 | 2.2 | 4.7 |
| *Typha latifolia* | – | – | 1.8 | 4.5 | 2.7 | 1.7 |

[1]Fraction A was the part extracted with chloroform from an ammoniacal solution and Fraction B was the part extracted with chloroform : ethanol (3:2) after addition of sodium sulphate.
(–) absence; (+) presence.

fore, provide an important source of supplementary protein in animal feeds as well. These plants had lower fibre but higher fat, ash and moisture contents when compared to roughages. High ash values in some plants would be of limited feed value but if plants are used to supplement animal feeds and not comprise the entire diet then the high mineral content of such plants should not pose a significant problem. Another negative aspect of aquatic plants is their high moisture content. Plants which have been partially dewatered by chopping and pressing can be fed directly to livestock. Some weeds like *Allmania nodiflora, Ipomoea reptans* and *Enhydra fluctuans* can be used directly as animal feed while some can be dried and incorporated into animal rations in appropriate proportions.

On the basis of an overall nutrient composition, twelve plants were found to contain sufficient quantities of nutrients and were safe enough to be considered as potential livestock feed. These plants are: *Allmania nodiflora, Azolla pinnata, Enhydra fluctuans, Eichhornia crassipes, Ipomoea reptans, Hydrilla verticillata, Lemna minor, Limnanthemum cristatum, Limnophila heterophylla, Lippia geminata, Marsilea quadrifolia* and *Pistia stratiotes*. Further studies on other aspects of feed quality such as palatability and digestibility experiments on these plants should be initiated. Owing to the acute shortage of fodder in India, utilization of aquatic plants as animal feed is particularly attractive for the better productivity of livestocks which comprise an integral part of the agricultural system.

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